The impact of guidelines on the use of imaging in osteoarthritis: a time trend analysis using electronic health record data

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Declaration

Dr John Edwards, Dr Michelle Marshall and Professor George Peat developed the research proposal for this thesis. The systematic review was informed by advice from Dr Nadia Corp, Dr Opeyemi Babatunde and Mrs Jo Jordan. Simran Parmar, Jordan Higgs and I undertook the screening of search results, while myself and Kane Treadwell undertook the critical appraisal of guidelines.

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Abstract

The National Institute for Health and Care Excellence (NICE) suggests there is no role for routine radiography in the diagnosis of osteoarthritis (OA). It is not known how consistent this recommendation is across guidelines, or the impact of guidelines on the use of radiography in OA.

A systematic review of current guidelines identified 18 OA guidelines published between 1998 and 2019. Most recommended a clinical diagnosis of OA irrespective of joint site, although only three explicitly discouraged the routine use of plain radiographs to confirm the diagnosis of OA.

An analysis conducted from 2000-2015, on primary care electronic health record data from nine practices on the North Staffordshire CiPCA database, identified 23,784 patients with at least one recorded OA consultation. The highest annual rate of X-ray requests in patients consulting for OA was 31.8% in 2015. Those receiving an X-ray referral tended to be aged 55-64 years (adjusted OR=1.15 Ref: 45-54), consult more frequently (≥10 times from 2000-2015 adjusted OR=11.69 Ref: 1-3 times) and registered to certain GP practices (for example Practice 2 adjusted OR=1.58 Ref: Practice 1).

A time-trend joinpoint analysis, restricted to the period 2000-2012, prior to the introduction of electronic X-ray requesting and reporting, was undertaken to determine whether the rate of X-ray requests changed over time and whether any such change coincided with the publication of four relevant UK guidelines. From 2000-2003, I Identified a slight increasing trend in X-ray request rates. From 2003-2012, I identified a slight decreasing trend in X-ray request rates. From 2000-2012, four prominent national guidelines discouraged routine radiography to confirm OA, however only one joinpoint detected a change in the underlying trend in X-ray request rates. Consequently, it was concluded that guidelines may have a limited impact on reducing X-ray use in primary care.

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Abbreviations and acronyms

ACR	American College of Rheumatology
ACR-A	American College of Radiology-appropriateness criteria: chronic ankle pain
ACR-EJP	America College of Radiology-appropriateness criteria: chronic extremity joint pain-suspected inflammatory arthritis.
ACR-F	American College of Radiology-appropriateness criteria: chronic foot pain
ACR-H	American College of Radiology-appropriateness criteria: chronic hip pain
ACR-K	American College of Radiology-appropriateness criteria: chronic knee pain
ACR-W	American College of Radiology-appropriateness criteria: chronic wrist pain
APTA	American Physical Therapy Association
BCW	Behaviour Change Wheel
BOA	British Orthopaedic Association
CI	Confidence Interval
CiPCA	Consultations in Primary Care Archive
CPRD	Clinical Practice Research Datalink
CPG Infobase	Clinical Practice Guideline Infobase
DIG	Diagnostic Imaging Guideline
EHR	Electronic health records
EULAR	European League Against Rheumatism

EULAR/EFFORT	European League Against Rheumatism & European Federation of National Associations of Orthopaedics and Traumatology
EULAR-H	European League Against Rheumatism-evidence based recommendations for the diagnosis of hand OA: report of a task force of ESCISIT
EULAR-K	European League Against Rheumatism-evidence based recommendations for the diagnosis of knee OA.
EULAR-PJ	European League Against Rheumatism-recommendations for the use of imaging in the clinical management of peripheral joint OA
GPs	General Practitioners
IMD	Index of Multiple Deprivation
IQR	Inter-Quartile Range
MaHTAS	Malaysia Health Technology Assessment Section
NICE	National Institute for Health and Care Excellence
NSAIDS	Non-Steroidal Anti-Inflammatory Drugs
OA	Osteoarthritis
OR	Odds Ratio
RACGP	Royal Australian College of General Practitioners
RCR	Royal College of Radiology
RCT	Randomised Controlled Trial
SIR	The Italian Society for Rheumatology-
VA/DOD	Department of Veterans Affairs & Department of Defense

1 Background

1.1 Definitions of osteoarthritis

Osteoarthritis (OA) is a difficult disease to define. OA can be broadly described as a complex joint disease resulting from multiple pathological pathways resulting in changes to the subchondral bone, ligaments, joint capsule, synovial membrane, and peri-articular muscle (Brandt, Dieppe & Radin, 2009). Clinically, these patients present with symptoms such as pain, no, or brief morning stiffness, and reduced mobility. Examination signs include joint crepitus, restricted movement, and bony enlargement (Hunter & Felson, 2006).

Within epidemiology, no clear gold standard exists for identifying OA cases (Kraus *et al.*, 2015). Current definitions describe the pathology, imaging or clinical features of OA, but each definition is criticised for failing to completely capture the complexity of OA (Kraus *et al.*, 2015; NICE, 2014a; Pritzker *et al.*, 2006; Castañeda *et al.*, 2014). The lack of a single agreed definition contributes to heterogeneous estimates of the prevalence of OA (Pereira *et al.*, 2011). Consequently, an understanding of the various definitions of OA are necessary to interpret the epidemiological research.

1.1.1 Pathological identification

Joint dissection allows for the anatomy of the joint to be examined for macroscopic signs of OA including osteophytes, and eburnations, the sclerotic reaction resulting from bone-on-bone articulation (Wallace *et al.*, 2017; Pritzker *et al.*, 2006). Microscopically, the Osteoarthritis Research Society International (OARSI) have developed a grading system to determine the severity of joint disease through the examination of bone and cartilage (Pritzker *et al.*, 2006) (Table 1-1).

Table 1-1: The OARSI histopathological grading system for the examination of bone and cartilage to identify osteoarthritis (Pritzker et al., 2006)	
Grade	**Key Feature**
Grade 0	Surface intact, cartilage morphology intact
Grade 1	Surface intact, cartilage morphology disturbed
Grade 2	Surface discontinuity
Grade 3	Vertical fissures
Grade 4	Erosions
Grade 5	Denudation of bone
Grade 6	Deformation of bone

1.1.2 Imaging

1.1.2.1 Radiography

A less invasive method to diagnose OA involves the use of radiographs. Radiographs can identify macroscopic signs of OA including loss of joint space, osteophytes, bone sclerosis and bony deformities. These macroscopic findings can be graded through the Kellgren-Lawrence classification system to assess disease severity (Kellgren & Lawrence, 1963) (Table 1-2). The Kellgren-Lawrence classification system is the most used radiological criteria to identify and grade OA (Schiphof, Boers & Bierma-Zeinstra, 2008; Dagenais, Garbedian & Wai, 2009; Trivedi *et al.*, 2010; Marshall *et al.*, 2008).

However, the Kellgren-Lawrence classification system has several limitations. First, inconsistent interpretations of the grading system have led to heterogeneity in identifying OA cases. This has led to variation in prevalence estimates (Schiphof, Boers & Bierma-Zeinstra, 2008). Secondly, a Kellgren-Lawrence grade 2, which signified the development of osteophytes, is considered the threshold for OA (Kohn, Sassoon & Fernando, 2016). This has led to criticism as it may over-emphasise the role of osteophyte formation in the natural history of OA. As a result, patients who have joint space narrowing but no osteophytes are not classified as having OA (Kohn,

Sassoon & Fernando, 2016). Finally, although X-rays are frequently used due to their low cost and availability, they are limited to only viewing bony structures in joints and may over-estimate the prevalence of OA (Hayashi, Roemer & Guermazi, 2016; Bedson & Croft, 2008).

Table 1-2: The Kellgren-Lawrence radiographic classification system osteoarthritis of the hip (Kellgren and Lawrence, 1963)

Grade	Key Feature
Grade 0	• No features
Grade 1	• Doubtful narrowing of joint space • Possible osteophyte lipping • Possible osteophytes
Grade 2	• Definite osteophytes • Possible narrowing of joint space
Grade 3	• Moderate multiple osteophytes • Definite narrowing of joint space • Some sclerosis • Possible deformity of bone ends
Grade 4	• Marked narrowing • Large osteophytes • Severe sclerosis • Definite deformity of bone ends

1.1.2.2 Magnetic Resonance Imaging

Magnetic resonance imaging (MRI) is able to visualise the articular cartilage, meniscus, ligaments, synovium and bone marrow (Guermazi *et al.*, 2012). The high cost of MRI makes it unsuitable for typical cases of OA. Furthermore inconsistent agreement has been found between MRI findings and clinical symptoms (Hunter *et al.*, 2013) . However, Hayashi, Roemer & Guermazi (2016) suggest that MRI has the potential to detect pre-radiographic OA changes.

OARSI, through a Delphi study, have produced criteria to identify knee OA through MRI (Hunter *et al.*, 2011). Tibiofemoral OA can be defined as present if a patient has either both group A features or one group A feature and two or more group B features (Table 1-3). Group A features

must be found in the absence of joint trauma and inflammatory arthritis which are identified through radiography and laboratory investigations.

Table 1-3: The magnetic resonance imaging criteria for the identification of tibiofemoral osteoarthritis as produced by the Osteoarthritis Research Society International (Hunter et al., 2011)

OA criteria: Either both group A feature or one group A features and two or more group B features

Group A	**Group B**
• Definite osteophyte formation	• Subchondral bone marrow lesions or cysts not association with meniscal or ligamentous attachments
• Full thickness cartilage loss	• Meniscal subluxation, maceration, or degenerative tear
	• Partial thickness cartilage loss
	• Bone attrition

1.1.2.3 Ultrasound definition

Ultrasound offers a low cost alternative to MRI in visualising soft tissue structures, in particular the synovium (Keen & Conaghan, 2009). Particularly, ultrasound is used frequently when investigating OA of the hand due to its ability to detect inflammatory changes associated with erosive OA (Vlychou *et al.*, 2009; Kortekaas *et al.*, 2011). Although ultrasound's utility in OA is in its early stages, a preliminary scoring system has been developed to identify OA, relying on the presence of both osteophytes and synovitis (Keen *et al.*, 2008).

1.1.3 Combined radiological and symptomatic definition

Despite many emerging imaging modalities, radiographs are the most frequently requested for OA. However, patients may have structural features of OA, but no clinical symptoms (Skou, Thomsen & Simonsen, 2014). To capture patients with both structural features and clinical symptoms, a combined radiological and symptomatic definition is used. A combined radiological

and symptomatic definition of OA includes radiographic features of OA and “pain in a joint on most days of a recent month” (Lawrence *et al.*, 2008)).

The combined radiological and symptomatic definition is likely to be more clinically relevant as it identifies patients with symptoms of OA who may go on to seek treatment. As a result, prevalence estimate using this combined definition may be more relevant for policy and health governance. However, joint pain is an indicator of OA but not pathognomonic. Consequently defining OA as pain associated with radiographic signs may result in false positives, attributing joint pain to OA in individuals with other pathological conditions such as bursitis (Hill *et al.*, 2003). In addition, the combined radiological and symptomatic definition of OA does not completely account for patients interactions with the health care system. As OA is managed predominantly within general practice, the primary care electronic health record (EHR) is a good source of information to assess patient care (Agniel, Kohane & Weber, 2018; Yu *et al.*, 2017).

1.2 Electronic health records

EHRs collect routine clinical information on patients during their interaction with the health service (Agniel, Kohane & Weber, 2018). Since the middle of the 1990s consultation data has been recorded in the UK using Read codes, a hierarchical classification system of clinical terms (Chisholm, 1990; Benson, 2011). More recently Read codes have been replaced by a new set of codes called SNOMED Clinical Terms (De Lusignan, Chan & Jones, 2011).

Routinely collected consultation data can be pseudo-anonymised and incorporated into a primary care databases (Verheij *et al.*, 2018). The Royal College of General Practitioners Weekly Returns Service is an example of a national database utilising EHR data. Using this database in 2001, it was estimated that 276 per 10,000 people aged 16 years or over had OA (Jordan *et al.*, 2007). Although this is a national database, local databases have shown similar disease prevalence estimates, with the Consultations in Primary Care Archive (CiPCA) database estimating the consultation prevalence of OA to be 232 per 10,000 people aged ≥16 years of age (Jordan *et al.*, 2007). As these data reflect patients presenting to health care services,

consultation database-derived information may be more relevant to policy makers and health care planners than estimates of prevalence produced using a combined symptomatic and radiographic definition of OA.

1.3 Prevalence of osteoarthritis

OA affects 240 million people globally (OARSI, 2016). Cross *et al.* (2014) estimated the global age-standardised combined radiological and symptomatic prevalence of OA to be 3.8% for the knee and 0.85% for the hip. Osteoarthritis of the hand and foot joints is not yet included in Global Burden of Disease models. In their systematic review, Pereira *et al.* (2011) found that OA is most prevalent at the hand, and least prevalent at the hip although this did not consider foot OA. Similarly, Peat *et al.* (2020) confirmed Pereira's observation that symptomatic radiographic OA is most prevalent at the hand, showing in addition that the prevalence of symptomatic radiographic foot OA is only slightly lower than knee OA.

1.4 Incidence of osteoarthritis

Oliveria *et al.* (1995) produced age and sex standardised estimates for the incidence of combined radiological and symptomatic OA. The highest incidence rate was found at the knee (240/100,000-person-years) followed by the hand (100/100,000 person-years) followed by the hip (88/100,000 person-years).

1.5 Impact of osteoarthritis

OA is a prevalent condition, which has ramifications for the individual, health care system and broader society.

1.5.1 Burden to the individual.

The most concerning symptom of OA experienced is pain (Arthritis Research, 2013). The pain arising from OA has been described as a dull, aching pain, that is initially intermittent and activity dependent (Hunter & Bierma-Zeinstra, 2019).

OA is also a disabling condition, contributing to more years lived with disability (YLD) than rheumatoid arthritis, bipolar affective disorder and HIV/AIDS (James *et al.*, 2018). The mobility impairment resulting from OA may inhibit effective medical management of other co-morbid conditions, resulting in deterioration in their overall health and higher rates of mortality (Schellevis *et al.*, 1993; Nüesch *et al.*, 2011; Hall *et al.*, 2016).

Severe mobility impairment prevents patients with OA from being able to care for themselves. 25% of individuals with OA cannot perform their activities of daily living, and 11% of individuals with knee OA need help with personal care (OA Research Society International, 2016; Guccione *et al.*, 1994). Consequently, these individuals have reduced social participation, which can affect their psychological wellbeing. This, among other reasons including chronic pain, low self-esteem and chronic fatigue, is thought to contribute to patients with OA being nearly twice as likely to suffer with depression than patients without OA (Shang *et al.*, 2019)

1.5.2 Health care burden

The impact of OA on an individual may have repercussions for the health care service. The cost of musculoskeletal conditions is huge, with the two most common conditions, OA and rheumatoid arthritis costing the NHS £10.2 billion in 2018, and over the next decade will have cumulatively cost £118.6 billion (Versus Arthritis, 2019)

It is assumed that most of the imaging activity for osteoarthritis concerns the hip and knee, rather than the hand and foot. However, the UK studies analysing X-ray requests for OA do not provide evidence for relative imaging activity based on joint site (Yu *et al.*, 2017; Jordan *et al.*, 2017; Edwards, 2017). The most common joints operated on are the hip and knee. In 2017, the overall cost to the NHS was £897 million for total hip replacements, and £1007 million for total knee replacements (Judge *et al.*, 2020). Regardless of joint site, in 2013, 8.75 million people received treatment for OA in the UK (Arthritis Research, 2013).

1.5.3 Societal burden

Indirect costs make up the largest proportion of the burden of OA. Indirect costs encompass lost productivity due to absenteeism, presenteeism, reduced employment rates and early retirement (Arthritis Research UK, 2016). A 2012 UK survey of OA patients found that of those under 65 years of age, 25% had given up work due to their OA, and a further 15% had changed their type of work or reduced their hours (Conaghan *et al.*, 2015). These significant costs of OA are international, with the cost of OA in Australia, France, UK, USA and Canada representing 1.0%-2.5% of the country's gross national product (Hunter, Schofield & Callander, 2014).

1.6 Future projection of osteoarthritis

The prevalence of OA is expected to rise. In Sweden, OA across any site is projected to rise 10% by 2032 (Turkiewicz *et al.*, 2014). The expected prevalence increase is attributed mainly to OA at the hip and knee joints, suggesting that these joint sites are likely to continue to have the largest burden on healthcare systems. The projected rise in the incidence of OA can be attributed to risk factors such as obesity and old age (Turkiewicz *et al.*, 2014).

1.7 Risk factors for osteoarthritis

An understanding of the risk factors for OA can improve early detection and facilitate targeted prevention strategies (Table 1-4) (Chu *et al.*, 2012).

Table 1-4: The systemic and local risk factors for osteoarthritis across all joint sites (Felson *et al.*, 2000; Nevitt *et al.*, 2001)

Systemic Risk Factor	**Local Risk Factor**
Age	Obesity
Sex	Joint injury
Genetic predisposition	Repetitive stress due to occupations and hobbies
Ethnicity	Joint deformity and malalignment
Obesity	

1.7.1 Systemic risk factors

1.7.1.1 Age

The prevalence of OA across all joint sites increases with age, but this relationship appears to be strongest for OA of the knee (Peat *et al.*, 2020). Radiographic knee OA is estimated to be 8% in those 40-49 years of age, rising to 61% in those aged 60 years or older (Ho-Pham *et al.*, 2014). Across all joint sites, by 65 years of age, 80% of the population have radiographic OA (Issa & Sharma, 2006). The incidence of OA in all joints appears to level off around age 80 (Oliveria *et al.*, 1995).

1.7.1.2 Sex

There is increasing evidence that sex is associated with OA prevalence. Pereira *et al.* (2011) found that female sex was associated with knee OA but not hand and hip OA. More recently, a study by Peat *et al.* (2020) found that female sex is associated with knee, hand, and foot combined radiological and symptomatic OA, with the exception of the non-nodal interphalangeal subtype of hand OA and the medial tibiofemoral subtype of knee OA.

Females and males <55 years of age have similar severity of OA across the hip, knee, and hand (Srikanth *et al.*, 2005). However, females ≥ 55 years of age have more severe knee OA when compared to men >55 years of age (Srikanth *et al.*, 2005). The reasons for this are unclear.

1.7.1.3 Genetics

Zhang & Jordan (2010) estimated that 30-65% of the risk of OA is genetically determined, and stronger for hip and hand OA, when compared to knee OA. Examples of this can be found within twin studies, which show a 61% heritability in radiographic hip OA (MacGregor *et al.*, 2000). Three categories of genes are thought to predispose patients to OA. Marshall *et al.* (2018) categorised these as genes associated with growth factor signalling, genes associated with the calcification of the extracellular matrix and genes associated with inflammatory pathways. Clustering of gene alleles may partly explain the disparity of OA prevalence between ethnicities (Panoutsopoulou & Zeggini, 2013).

1.7.1.4 Ethnicity

Caucasian individuals have higher rates of radiographic hip and hand OA when compared to individuals of Chinese descent (Zhang *et al.*, 2003; Nevitt *et al.*, 2002). However, Chinese individuals have similar rates of radiographic knee OA when compared to Caucasians (Zhang *et al.*, 2001). These differences between ethnicities are likely a result of both genetic and cultural factors. A cultural factor hypothesised to partially explain the lower rate of hip OA in Chinese individuals is the greater adoption of a squatting position (Garstang & Stitik, 2006). This position strengthens the muscles surrounding the hip joint, contributing to improved joint stability (Buckwalter, 1995; Müller *et al.*, 1994).

Ethnic differences also vary between genders. African American men have higher rates of radiographic hip OA when compared to Caucasian men, however this ethnic disparity disappears in women (Jordan *et al.*, 2009).

1.7.2 Local factors

1.7.2.1 Obesity

There is a strong relationship between obesity and OA of load bearing joints (Thomas *et al.*, 2015). Individuals with a BMI ≥36 kg/m^2 are at a 13.6 times increased odds of developing knee OA when compared to those with a BMI ranging from 24.0-24.9 (Coggon *et al.*, 2001). This is due to increased mechanical force being applied across the loading joint resulting in joint inflammation (King, March & Anandacoomarasamy, 2013)

Obesity also increases the risk of OA in non-weight bearing joints. Reyes *et al.* (2016) found that patients with a BMI ≥35 kg/m^2 were 31% more likely to develop OA when compared to individuals with a BMI <25 kg/m^2. This is because adipose tissue stimulates the production of inflammatory hormones which drives OA inflammatory pathways. This may lead to cartilage degradation (Kapoor *et al.*, 2011). For this reason, obesity can be viewed as both a local and a systemic risk factor for OA (King, March & Anandacoomarasamy, 2013).

1.7.2.2 Joint injury

Similarly, injury can result in abnormal mechanical forces being placed across the joint. This is because injury to a joint may disrupt the ligamentous, tendinous, and cartilaginous architecture, disrupting articulation (Buckwalter *et al.*, 2013). The disrupted biomechanics can result in excessive stress on the cartilage and bone which may lead to OA (Lieberthal, Sambamurthy & Scanzello, 2015).

1.7.2.3 Occupation and Hobbies

Repetitive stress or large forces being placed across a joint can induce joint damage which may lead to OA (Messier *et al.*, 2009). For this reason certain activities and occupations are associated with OA at specific joint sites: knee OA is associated with carpet fitters, hip OA is found more frequently in famers and hand OA is more prevalent in rock climbers and with the repetitive use of chopsticks (Thomas *et al.*, 2015; Croft *et al.*, 1992; Palmer, 2012; Schöffl *et al.*, 2018).

1.8 Current management of osteoarthritis in primary care

For healthcare policies to provide high value care they should improve patient and population health at a reduced cost. This is described as the Triple Aim (Berwick, Nolan & Whittington, 2008). However, the Triple Aim does not acknowledge the benefits of improving the experience of the workforce. Therefore, an updated framework described as the Quadruple Aim recognises that healthcare policies should also aim to improve the experiences of those providing the care (Sikka, Morath & Leape, 2015). Guidelines enable practitioners to provide the best care to patients whilst minimising the use of unnecessary interventions and inappropriate investigations (Insitute of Medicine, 2011).

Within the UK, the National Institute for Health and Care Excellence (NICE) published guidelines for the management of OA in primary care. NICE treats OA as a single disease, with no explicit management variation based on joint site (NICE, 2014a).

When assessing patients, NICE outlines the importance of a holistic assessment considering the biological, psychological, and social consequences of OA. Additionally, NICE (2014b) recommends

a clinical diagnosis of OA, however in patients with atypical presentations further investigations may be indicated.

NICE outlines core management strategies for all patients identified as having OA. Non-pharmacological strategies include education on the disease process, exercise, and weight loss. Add on therapies such as thermotherapy, electrotherapy, appropriate footwear, joint supports, and assistive devices such as walking sticks are recommended at the discretion of the treating physician.

Pharmacological management focuses on relieving pain. Paracetamol and topical non-steroidal anti-inflammatory drugs (NSAIDS) are recommended as first line treatments for patients with OA. Alternatives, such as oral NSAIDS and opioids may be trialled if pain is not appropriately managed. Further adjuncts can be offered to help manage pain, such as capsaicin and intra-articular corticosteroid injections.

Definitive joint surgery should be offered to patients if significant symptoms remain which reduce quality of life, despite the trialling of non-surgical treatment options (NICE, 2014a). However, symptoms may remain following surgery (Jones *et al.*, 2007; Brooks *et al.*, 1999).

NICE guidelines are unclear as to the role of radiography in determining the suitability of a patient for joint surgery. However, specialist guidelines produced by the Royal College of Surgeons recommend radiographs in the assessment of a patient's suitability for joint replacement (Price *et al.*, 2017).

1.9 Non-adherence to guidelines

The diagnosis and management of OA within the community does not closely follow guideline recommendations (Porcheret, Jordan & Jinks, 2007; Denoeud *et al.*, 2005; DeHaan *et al.*, 2007; Hunter, 2010). Significant barriers have been identified to explain the lack of adherence to guidelines, including lack of agreement between guidelines, guidelines that are too long and seem inaccessible, and a lack of awareness of guidelines (Fischer *et al.*, 2016; Gransjøen *et al.*,

2018). A particular area of non-adherence seems to be in the use of radiography to diagnose OA (Smink *et al.*, 2014a; Morgan *et al.*, 1997; Jacob & Thampy, 2015; Yu *et al.*, 2017; Brand *et al.*, 2014).

1.10 Diagnosing osteoarthritis

As mentioned above, NICE indicates that OA at any site should be diagnosed clinically. Similarly, the European League Against Rheumatism (EULAR) and American College of Rheumatology (ACR) have produced clinical diagnostic criteria for OA (Table 1-5). This suggests that some guideline organisations prefer a clinical diagnosis over a radiographic diagnosis of OA. However, the consistency of this recommendation between national and international guidelines is not known.

Table 1-5: The NICE clinical diagnostic criteria for any joint, the ACR knee clinical diagnostic criteria and the EULAR knee clinical diagnostic criteria for osteoarthritis (Altman *et al.*, 1986; NICE, 2014a; Zhang *et al.*, 2010)

NICE: All joint sites (2014)	**ACR: Knee (1986)**	**EULAR: Knee (2010)**
• >45 years of age *And* • The presence of activity related joint pain *And* • No morning related joint stiffness or morning stiffness lasting less than 30 minutes.	• >38 years of age *And* • Crepitus and morning knee stiffness of 30 minutes or less *Or* • Crepitus, morning stiffness lasting longer than 30 minutes and bony enlargement *Or* • No crepitus but bony enlargement	• >40 years of age *And* • Movement related joint pain *And* • Morning knee stiffness of less than 30 minutes *And* • Functional limitations *And* One of the following examination findings: • Crepitus • Restricted range of motion • Bony enlargement

NICE: National institute for Health and Care Excellence, ACR: American College of Rheumatology, EULAR: European League Against Rheumatism

1.11 The value of routine radiography in primary care

Chapter three reports on a systematic review of national and international guidelines on the role of imaging in the diagnosis of OA. The following highlights why routine radiography may not be appropriate for the diagnosis and management of OA.

1.11.1 Diagnostic utility

Inconsistent agreement between radiographic criteria and diagnostic criteria for OA reduces the utility of radiography in clinical practice (Kinds *et al.*, 2011). Radiographic features are not always present in patients with OA (Kim *et al.*, 2015; Bedson & Croft, 2008), and an over-reliance on radiographic features may cause doctors to under-appreciate a patient's symptoms (Rosemann *et al.*, 2006a). Instead they may look to alternative differential diagnosis, such as depression, as a cause for their patients symptoms (Rosemann *et al.*, 2006b). This may appear to patients as doctors trivialising their symptoms, which erodes the doctor-patient relationship (Alami *et al.*, 2011). This has the potential to lead to more diagnostic inaccuracy in future care and reduced engagement in medical management (Schmidt *et al.*, 2017; Miller *et al.*, 2016).

1.11.2 Delays in management

Radiographic features often appear late in the disease process (Felson & Hodgson, 2014). If practitioners perceive structural changes as necessary to start core treatments, this can result in treatment delays, which may mean patients spend more time with pain and disability (Fransen *et al.*, 2015; Penninx *et al.*, 2001; De Klerk *et al.*, 2012).

1.11.3 Altering management

An additional disadvantage of X-rays is that they reinforce negative perceptions that OA is a progressive disease caused by 'wear and tear', and is ineffectively treated with self-management strategies (Darlow *et al.*, 2018). This biomedical model causes patients to believe that they must protect their joints, causing them to limit or disengage with exercise treatments (Darlow *et al.*,

2018). This structural perception may also make patients believe the damage is permanent. With reduced engagement in core activities, symptoms fail to improve which may result in earlier and inappropriate orthopaedic referrals (Grime & Ong, 2007; Hannan, Felson & Pincus, 2000; Glazier *et al.*, 1998). An alternative explanation for inappropriate orthopaedic referrals is that severe X-ray features have been associated with a worse perception of a patient's quality of life (Rosemann *et al.*, 2006a). As quality of life is an indicator for joint replacement, this could explain why patients who have severe radiographic features are more likely to be referred for a total joint replacement, independently of other factors such as age, gender and pain (Dolin *et al.*, 2003).

1.11.4 Radiography is an inefficient use of resources

X-rays are relatively cheap to perform. However, when applied to a highly prevalent condition like OA they become a significant, potentially avoidable, cost to health care systems. The preference of NICE (2014b) towards a clinical diagnosis over a radiographic diagnosis may partially reflect an opportunity for efficiency savings in the context of an investigation with little additive value to the care of OA patients (Grant *et al.*, 2012).

To my knowledge, the extent to which X-rays are used in primary care for OA has been explored in seven studies conducted over the past 23 years in four countries. Details are outlined below.

1.11.5 The use of X-rays for osteoarthritis in primary care

Glazier *et al.* (1998) emailed paper cases to 798 Canadian family physicians to assess how X-rays are used to manage knee OA. Of the 529 responses, 88.5% of practitioners recommended radiography for a routine case of knee OA. The research team interpreted this as a correct use of investigations, highlighting how there has been a shift in the understanding of the role of X-rays in OA over the last 20 years.

More recently, despite growing evidence for a clinical OA diagnosis without a need for routine radiography (Zhang *et al.*, 2010), an Australian study conducted from 2005-2010 found that 45% of first time consulters for knee OA received an X-ray in primary care (Brand *et al.*, 2014). In the

context that X-rays do not correlate well with structural features, and OA can be diagnosed clinically, this could be interpreted as an excessive use of X-rays despite guideline recommendations (Bedson & Croft, 2008). Similarly, a 2013 Dutch study found that following two years of patients and practice education, only 44% of X-ray requests for knee and hip OA followed guideline recommendations (Smink *et al.*, 2014a). Unfortunately, this Dutch study only assessed X-ray use following an intervention, and as a result provides little generalisability on the baseline use of X-rays for OA in the Netherlands. Additionally, the degree to which these X-ray requests are inappropriate is also uncertain, as none of the above studies assessed the consultation data to determine the appropriateness of the X-ray request. Finally, as these studies were conducted in non-UK practices, their findings may hold little generalisability to the UK (Brand *et al.*, 2014).

Only two studies have assessed the appropriateness of X-ray requests for OA in the UK. In 1997, an audit conducted at the Leicester Royal Infirmary identified 1152 X-ray requests over a 9-month period (Morgan *et al.*, 1997). The audit assessed if radiology referrals for OA of the knee complied with Royal College of Radiology (RCR) 1995 guideline recommendations which discouraged routine radiography for OA. Morgan et al. (1997) found that only 50% of X-ray requests complied with RCR recommendations. This provides evidence that X-rays have been over-used in the diagnosis and management of OA in the UK. However, over the last 20 years changing patients attitudes, access to imaging services and awareness of guidelines recommendations have changed how primary care practitioners use diagnostic investigations (O'Sullivan *et al.*, 2018). This may reduce the relevance of this finding to modern clinical practice.

A 2013 UK study analysed the appropriateness of 25 knee X-ray requests by general practitioners, of which only 52% adhered to RCR guideline recommendations (Jacob & Thampy, 2015). This study is limited as it only collected data from one OA site, for a 4-month period, at one practice. Consequently, the findings may be unsuitable to directly extrapolate to the rest of UK practice.

Few studies have examined the rate of X-ray requests in the UK. Yu *et al.* (2017) estimated that the 2013 UK rate of X-ray requests for incident cases of OA was 22% using the Clinical Practice Research Datalink (CPRD), a database of longitudinal pseudo-anonymised primary care data from 50 million patients across a 1900 primary care practices (CPRD, 2020). However, this estimate is likely an under-estimate of the use of X-rays for OA due to the lack of linked secondary care data and restricting the population to incident cases of OA. Similarly, a randomised controlled trial (RCT) conducted from 2012-2014 examined the impact of a practitioner education programme and a reminder system on a series of quality of life indicators, one of which was the rate of X-ray requests (Jordan *et al.*, 2017). In the intervention and control arms, the baseline rate of X-ray requests for OA was 25% and 3% respectively. This wide range provides evidence of uncertainty as to the true rate of X-ray requests for OA. Furthermore, no study has assessed how X-ray request rates for OA has changed over time

Several studies have attempted to understand why practitioners request X-rays for OA. These factors that drive the use of X-rays can be categorised into practitioner, patient, and structural factors.

1.11.6 Practitioner factors

Several practitioner factors have been suggested to influence the decision to X-ray a patient for OA (Table 1-6). Bedson, Jordan & Croft (2003) concluded that a GP's decision to X-ray had little to do with clinical symptoms and signs, and more to do with referral intentions. The decision to X-ray was associated with an increased likelihood of a rheumatology or an orthopaedic referral and a decreased likelihood of a physiotherapy referral. However, the rate of secondary care referrals following an X-ray is unknown.

Alternatively, GPs may feel more comfortable in making a diagnosis of OA in the presence of radiographic features due to lack of confidence in their ability to make a clinical diagnosis (Egerton *et al.*, 2018). Alternatively, practitioners may use radiographs to rule out other differential diagnosis. This may be due to a fear of the medico-legal repercussions of missing an

important differential diagnosis (Morgan *et al.*, 1997; Egerton *et al.*, 2018). However, the liability of not offering radiographs to patients with a typical OA presentation is likely low. To establish clinical negligence within the UK, three criteria must be fulfilled (Fearnley, Bell & Bodenham, 2012). Firstly, the patient must be owed a duty of care. Secondly, that duty of care must fall below the medical standard. Thirdly, this must result in some harm to the patient (Fearnley, Bell & Bodenham, 2012). Guidelines have been used in legal cases to represent the standard of care (Fearnley, Bell & Bodenham, 2012). As NICE (2014b) recommend a clinical diagnosis of OA, they in theory may be used as a threshold for medical care. Furthermore, the risk of harm to patients of not offering an X-rays is low (Skou, Thomsen & Simonsen, 2014). Consequently, NICE have reassured practitioners that it is safe to not X-ray a patient with typical OA symptoms and have stressed the confidence that can be placed on diagnostic criteria (NICE, 2014b). The medico-legal fears harboured by practitioners may be largely unfounded.

1.11.7 Patient factors

Patient pressure has been reported as a significant factor in 30% of knee X-ray requests (Morgan *et al.*, 1997). Hoffman et al. (2013) found that patients believe X-rays are necessary to find the cause of their pain. If doctors choose not to offer a patient an X-ray, this may be interpreted as a doctor not taking their OA seriously (Alami *et al.*, 2011). This lack of confidence in the practitioner's decisions may make patients feel that they must pressure doctors to receive the right care, resulting in the insistence on medical imaging (Spitaels *et al.*, 2017; Egerton *et al.*, 2018). The education of patients on the utility of X-rays could facilitate a reduction in X-ray request, however, the ability of GP's to re-educate patients is limited by structural factors such as time constraints.

Table 1-6: The barriers to adherence to radiographic recommendations discouraging the routine use of radiography, categorised into practitioner, patient, and structural factors (Egerton et al., 2018; Alami et al., 2011; Gransjøen et al., 2018; Bedson, Jordan & Croft, 2003)

Practitioner Factors	**Patient factors**	**Structural factors**
Confidence in clinical diagnosis	Lack of confidence in health care professionals	Time pressures
Habit	Patient expectations informed by media and lay members	Availability of imaging services
Fear of medico-legal repercussions	Lack of understanding of the disease process	
Lack of awareness of guidelines		
Guidelines being too long, rigid, or unclear		
Referral intentions		
Conversation aid for patient education		

1.11.8 Structural factors

The time constraint of consultations and the increased availability of imaging services may mean practitioners offer people X-ray in a strategic way to end consultations (Gransjøen *et al.*, 2018; O'Sullivan *et al.*, 2018). This strategic use of investigations is not specific to OA, and is speculated to occur throughout primary care (O'Sullivan *et al.*, 2018).

1.12 Summary

OA is a disease of the synovial joints resulting in pain, no, or only brief, morning stiffness and loss of mobility. It imposes a significant burden on the individual and broader society. NICE guidelines indicate that OA can be diagnosed clinically, however the consistency of this recommendation between guidelines and between joint sites is unknown. Data from 2013 indicate that X-rays are likely over-used in the diagnosis of OA, however it is unknown how the rate of X-ray requests has changed over time, and the impact guideline publications have had on the rate of X-ray request.

2 Thesis rationale, aims and objectives

2.1 Thesis Rationale

Osteoarthritis (OA) is a prevalent condition managed in primary care. Guidelines disseminate evidence-based recommendations to improve the consistency of care and ensure resources are used efficiently. The synthesis of evidence-based recommendations can improve the understanding of how OA should be managed in primary care. However, the methodological rigour of OA guidelines has been found to be variable (Misso *et al.*, 2008; Zhang *et al.*, 2007). Several systematic reviews have synthesised management recommendations for OA (Zhang *et al.*, 2007; Nelson *et al.*, 2014; Larmer *et al.*, 2014; Pencharz *et al.*, 2001), however only one systematic review synthesised diagnostic OA recommendations (Misso *et al.*, 2008) and several national guidelines have been released since its publication (NICE, 2014a; Royal College of Radiologists, 2017b; Zhang *et al.*, 2010, 2009; Bussières, Peterson & Taylor, 2008; Ariani *et al.*, 2019; Melorose, Perroy & Careas, 2013).

Currently the understanding of X-ray use for OA within UK primary care is limited by sparsity in literature specific to the UK (Brand *et al.*, 2014; Glazier *et al.*, 1998; Smink *et al.*, 2014a), data that may not be relevant to the current healthcare system (Morgan *et al.*, 1997; Glazier *et al.*, 1998), or studies with small sample sizes (Jordan *et al.*, 2017; Jacob & Thampy, 2015). Furthermore, although subsequent audits suggest the over-use of X-ray in OA (Morgan *et al.*, 1997; Jacob & Thampy, 2015), to my knowledge no study has assessed the rate of X-ray requests over time, or the association between X-ray request rates and the publication of OA guidelines.

2.2 Aim

The aim of this thesis is to undertake a systematic review and narrative synthesis of national and international guideline recommendations surrounding the role of radiography in the diagnosis of OA and investigate trends in the use of radiography for OA and the potential impact of guideline publications on X-ray use.

2.3 Objectives

- To undertake a systematic review and narrative synthesis of national and international guideline recommendations on the role of radiography in the diagnosis of osteoarthritis.
- Estimate the proportion of patients presenting to general practice with OA in whom an X-ray is requested, and changes in this proportion during the period 2000-2015
- Explore whether any changes over time in the above proportion coincided with the publication of relevant NICE and RCR guidelines.
- Estimate the proportion of patients who are referred to secondary care following an X-ray request for OA, and changes in this proportion during the period 2000-2015
- Estimate the direction and magnitude of association between measured patient characteristics and the likelihood of an X-ray being requested for OA.
- Explore the extent of variability between general practices in the proportion of patients with OA in whom an X-ray is requested

3 Systematic review of national and international guidelines on the diagnosis of osteoarthritis in primary care.

3.1 Introduction

The National Institute for Health and Care Excellence (NICE) does not recommend routine radiography to confirm a clinical diagnosis of osteoarthritis (OA). However, the extent to which this is consistently reflected across OA guidelines is unclear. This chapter presents a systematic review of national and international OA guideline recommendations regarding the use of X-rays for the diagnosis of OA across all joint sites.

3.1.1 Aim

To undertake a systematic review and narrative synthesis of national and international guideline recommendations on the role of radiography in the diagnosis of OA.

3.1.2 Objectives

The objectives of this systematic review are to:

- Identify important clinical features which improve the diagnostic certainty in a clinical OA diagnosis
- Describe to what extent guidelines recommend radiography to confirm a clinical diagnosis of OA
- Synthesis clinical diagnostic criteria for OA
- Describe to what extent other imaging modalities including MRI, ultrasound and CT are routinely indicated in the diagnosis of OA in primary care

3.2 Methods

3.2.1 Selection criteria

Inclusion and exclusion criteria can be found in Table 3-1. To ensure guidelines were evidence based, I only included guidelines developed through a systematic review of the evidence. Guidelines focusing on spinal OA and temporomandibular joint OA were excluded as the literature of these joints is often considered to be separate from the rest of OA literature (NICE, 2014b). The review protocol was registered on PROSPERO on the 28th November 2019. The reference code for the protocol is CRD42019155893 and can be found at Appendix 1.

Table 3-1: The Inclusion and exclusion criteria to identify national and international osteoarthritis diagnostic guidelines

Inclusion criteria	**Exclusion criteria**
Produced by professional organisations or guideline development groups	Guidelines focussing on spinal OA
Each guideline must include recommendations on the diagnosis of OA in patients over the age of 18	Guidelines focussing on temporomandibular joint disease
The guideline development process must include a systematic review of the evidence	Summaries of guidelines
	Grey literature
	Guidelines that are not reported in English
	Guidelines focusing only on OA management
	Previous editions of guidelines
	Guidelines where the full text is unavailable

3.2.2 Search strategy

The search strategy was developed with support from a health librarian. Details are provided below.

OA was defined as “osteoarthritis, OA, arthrosis and degenerative arthritis”. Guidelines were defined as “guideline development group, guideline, guidance, diagnostic criteria, recommendation, practice guideline, practice guidance, practice recommendation, clinical guideline, clinical guidance, clinical recommendation, diagnostic guideline, diagnostic guidance and diagnostic recommendation”. Truncation, field codes, and proximity searching was applied to improve the identification of relevant articles. MeSH terms relevant to OA and guidelines were also included. The search strategy was piloted on Medline and translated to other databases and search engines. A list of known guidelines was checked with the pilot search to ensure face validity. A systematic review specialist reviewed and approved the final search strategy. The final search strategy can be found in Appendix 2.

3.2.3 Databases searched

I searched core medical databases and guideline specific search engines, a summary of which can be found in Table 3-2. To ensure the search captured prominent OA guidelines that may not have been published on core medical databases, three academics with OA expertise including a professor of statistics and epidemiology (GP), a research fellow in musculoskeletal clinical epidemiology and imaging (MM), and a senior lecturer in general practice (JE) identified professional organisations which may have published OA guidelines. I then undertook a hand search of these professional organisation’s websites. All guideline sources were searched by the 30/10/2019.

Table 3-2: The sources searched to identify national and international diagnostic osteoarthritis guidelines

General medical database searched (Interface)	Guideline specific databases searched	Website searched (Acronym)
• MEDLINE (Ovid)	• TRIP	• European League Against Rheumatism (EULAR)
• Cumulated Index to Nursing and Allied Health Literature (EBSCO)	• Guideline Central	• National Institute for Health and Clinical Excellence (NICE)
• British Nursing Index (Healthcare Database Advanced Search)	• Clinical Practice Guidelines (CPG) Infobase	• Scottish Intercollegiate Guideline Network (SIGN)
• EMBASE (Healthcare Database Advanced Search)	• Guideline International Network	• American College of Rheumatology
• Healthcare Management Information Consortium (Healthcare Database Advanced Search)	• Epistemonikos	• British Society of Rheumatology (BSR)
• Allied and Alternative Medicine (EBSCO)		• Royal College of General Practitioners (RCGP)
		• Royal College of Radiology (RCR)
		• American College of Radiology (ACR)
		• Osteoarthritis Research Society International (OARSI)

3.2.4 Screening of search results

All search results were imported into a reference management software to remove duplicates (Mendeley, 2020). The search results were then exported to Rayyan, a results screening software (Ouzzani *et al.*, 2016). Screening occurred through three phases according to the pre-defined inclusion and exclusion criteria. All titles underwent single screening by CHB. The abstract and full text underwent dual screening through the following process. CHB screened all records. SP and JH screened 50% of the remaining records each. An independent reviewer, MM, settled all conflicts by majority decision.

3.2.5 Data extraction

CHB undertook the data extraction. All fields were checked independently by another researcher (KT). The extracted data were collated in an Excel table under the following headings:

- What is the name of the guideline?
- In which country or continent was the guideline published?
- Was the guideline new, adapted, or updated?
- What were the specialities of the guideline-development group members?
- Which professions were targeted?
- Which medical specialities were the target audience of the guideline?
- What diagnostic recommendations were made?
    - What was the grade of the evidence behind each recommendation?
    - Which joint site did the OA recommendation apply to?
- What were the clinical diagnostic criteria recommended for OA?
- What were the symptoms and signs of OA and which joint did they apply to?
- Which type of diagnosis of OA was recommended (clinical/ laboratory/radiographic or any combined)?
- What were the indications for additional investigations?
- Which imaging modality was recommended first line?

- Which X-ray views are recommended and for which joint?
- Did the guidelines discuss the scientific rationale for not requesting X-ray for OA, and if so, what were they?
- What were the future research questions identified?
- Did the organisation discuss competing interests?
- How was the guideline funded?

3.2.6 Quality assessment

Before assessing the guidelines, a decision was made not to email authors for additional unpublished information which would aid appraisal. This is because it is my opinion, which is consistent with the Institute of Medicine (2011), that in order to trust a guideline, its methodology should be transparent.

The guidelines were assessed against the AGREE II tool by CHB and KT (Brouwers *et al.*, 2010). An alternative to the AGREE II tool for guideline appraisal is the ICAHE tool (Grimmer *et al.*, 2014). I chose to use the AGREE II tool over the ICAHE tool as the ICAHE tool does not consider guideline applicability, a domain in which guidelines are frequently criticised (Gagliardi & Brouwers, 2015; Misso *et al.*, 2008). In preparation for appraisal, CHB and KT read the AGREE II manual in its entirety and completed the AGREE II online training modules.

This tool consists of twenty-three criteria across 6 domains. The criteria can be found in Appendix 3. The AGREE II domains include:

1. Scope and purpose
2. Stakeholder involvement
3. Rigour of development
4. Clarity of presentation
5. Applicability
6. Editorial independence

Each criterion is measured against a seven-point Likert scale. A rating of one out of seven indicates no information fulfilling the AGREE II criteria, a score of seven indicates a complete fulfilment of the AGREE II criteria. These criterion scores can be combined to produce a scaled domain score.

A scaled domain score is a weighted score that represents how well a guideline fulfils an AGREE II domain. The equation for a scaled domain score is illustrated in Figure 3-1.

Figure 3-1: Equation to calculate Agree II scaled domain scores

$$scaled\ domain\ score = \frac{(domain\ score) - (minimum\ possible\ score\ )}{(maximum\ possible\ score) - (minimum\ possible\ score)}$$

$$minimum\ possible\ score\ = \text{no. of items x no. of reviewers x } 1$$

$$maximum\ possible\ score\ = \text{no. of items x no. of reviewers x } 7$$

The AGREE II manual states that authors should decide their own cut off for determining if a guideline is of high quality. The rigour of development domain is reported to have the highest influence on guideline quality (Hoffmann-Eßer *et al.*, 2017), and a 50% cut off is generally accepted as indicating sufficient fulfilment of a domain (Parisi *et al.*, 2014; AGREE, 2018). As a result, I chose a rigour of development score >50% as representing a high-quality guideline, which is in line with other systematic reviews (Ferket, 2010).

3.2.7 Methods of narrative synthesis

A preliminary review of the data extraction spreadsheet identified four themes: risk factors, symptoms and signs, diagnostic recommendations, and imaging recommendations. Data were taken from the data extraction table and grouped by these themes. Within each theme, data were grouped into subthemes based on joint site. If a recommendation applied to more than one joint site, it was defined as a multiple joint recommendation. Additionally, areas of similarity between joint sites were combined.

3.3 Results

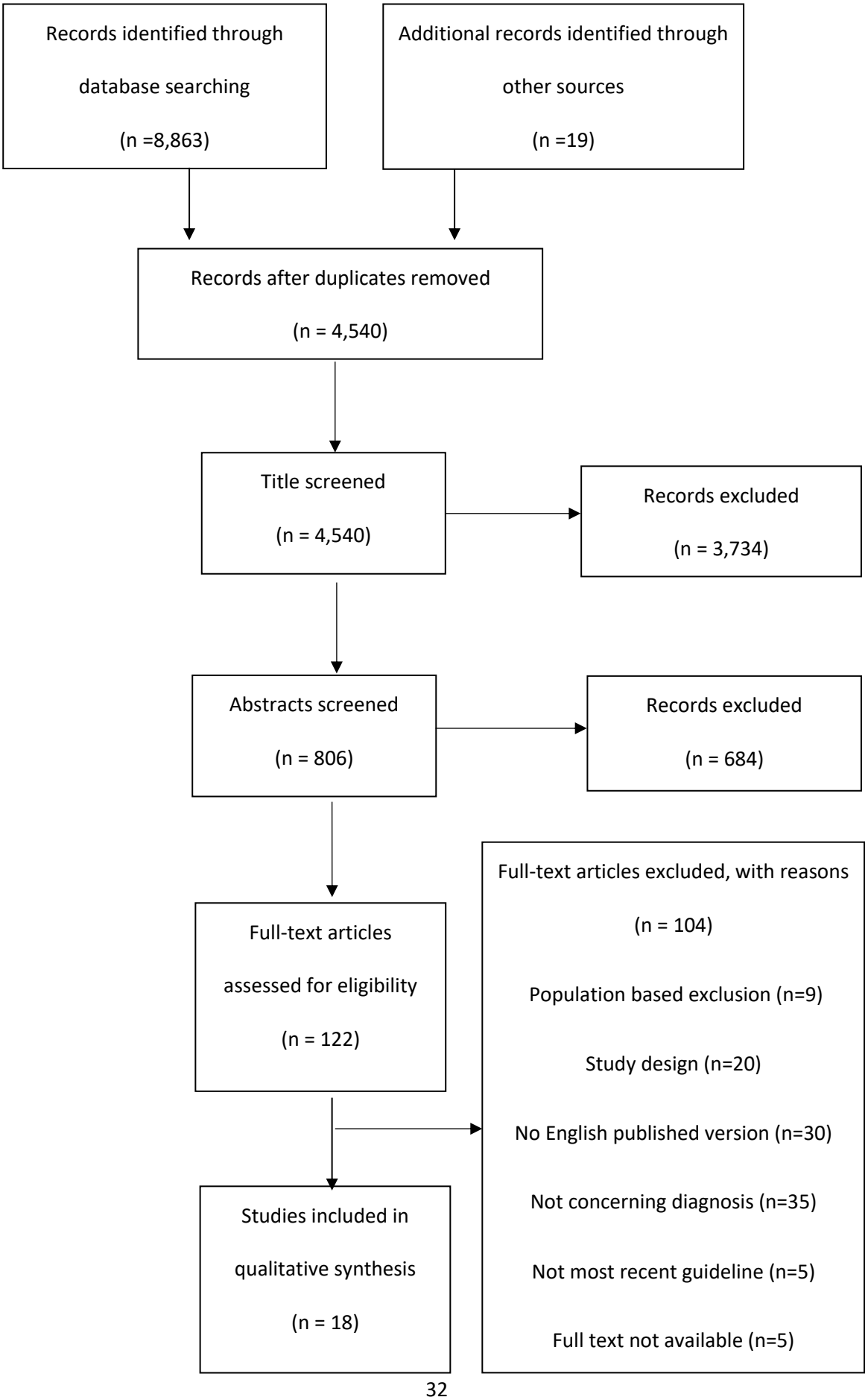
3.3.1 Articles retrieved

The systematic search revealed 8,882 records. EMBASE yielded most of the records. The number of records retrieved from each database is shown in Table 3-3. The software packages Mendeley and Rayyan were used to remove 4,342 duplicates. CHB title screened 4,540 titles, removing 3,734, leaving 806 records for abstract screening. Of the 806 abstracts screened 684 were excluded, leaving 122 articles for full text screening. Of the 122 full texts screened, 18 met the selection criteria and were suitable for inclusion in this review. Details outlining the reason for exclusion can be found in Figure 3-1.

Table 3-3: The number of records retrieved from each guideline source searched

Guideline source	**Number of records**
EMBASE	4,423
MEDLINE	2,403
Cumulative Index to Nursing and Allied Health Literature	1,293
TRIP	303
Allied and Alternative Medicine	172
Epistemonikos	163
British Nursing Index	55
Guideline Central	19
Health care Management Information Consortium	19
Guideline International Network	13
European League Against Rheumatism	8
American College of Radiology	6
Osteoarthritis Research Society International	3
Royal College of Radiology	1
National Institute for Health and Care Excellence	1
British Society of Rheumatology	0
Scottish Intercollegiate Guidelines Network	0
Royal College of General Practitioner's	0
American College of Rheumatology	0
Total	8,882

Figure 3-2: A PRISMA flow diagram highlighting the search screening process



3.3.2 Search result

A summary of the guideline characteristics is presented below. Further details of each guideline can be found in Table 3-4. The earliest evidence-based recommendations on the role of imaging in OA was published in 1998. Three guidelines were produced from 1999-2009. This figure more than tripled from 2010-2019, when fourteen guidelines were published. Eight guidelines managed OA as a multiple joint disease. Three guidelines were specific to knee OA; two guidelines were specific to hand or hip OA. One diagnostic OA guideline was published for each of the wrist, foot, and ankle joints.

Seventeen guidelines state their target audience as doctors, with sixteen guidelines also acknowledging allied health professionals and four guidelines stating patients were their audience too. The version of the "EULAR evidence-based recommendations for the diagnosis of hand OA: report of a task force of ESCISIT" (EULAR-H) guideline that I had access to did not explicitly state its target audience. A range of medical specialities were targeted, with nine guidelines targeted at radiologists, eight guidelines targeted at general practitioners, four guidelines targeted at rheumatologists and three guidelines targeted at orthopaedic surgeons.

Of the eighteen guidelines included in this systematic review, thirteen are new, four are updates and one is an adaptation.

Two guidelines did not provide details regarding their competing interests and one guideline did not provide details regarding their source of funding.

Two guidelines contained audit criteria, but only one guideline contained audit criteria for the diagnosis of OA.

A multi-disciplinary team produced or externally reviewed all guidelines. The number of guideline-development group members ranged from ten to 44, with a median of 17. The "iRefer: making the best use of clinical radiology" (RCR) guideline did not provide sufficient information to determine the number of guideline-development group members.

Table 3-4: The characteristics of the identified osteoarthritis diagnostic guidelines

Guideline	Country/ continent	Year of publication	Guideline developers	New/ updated/ adapted	Site of OA	Target audience	Medical speciality	Competing interests	Funding discussed	Rigour score
MaHTAS	Malaysia	2013	21	Updated	Multiple joint	Doctors Allied health professions Patients	Unclear	Yes	Yes	61%
ACR-EJP	United States	2017	18	New	Hand	Doctors Allied health professions	Radiologist	Yes	Yes	60%
ACR-A	United States	2018	17	New	Ankle	Doctors Allied health professions	Radiologist	Yes	Yes	56%
ACR-F	United States	1998	20	New	Foot	Doctors Allied health professions	Radiologist	Yes	Yes	70%
ACR-K	United States	2018	17	New	Knee	Doctors Allied health professions	Radiologist	Yes	Yes	70%
ACR-W	United States	2017	14	New	Wrist	Doctors	Radiologist	Yes	Yes	70%

						Allied health professions				
ACR-H	United States	2016	20	New	Hip	Doctors Allied health professions	Radiologist	Yes	Yes	70%
DIG	Canada	2007	44	New	Multiple joint	Doctors Allied health professions	Chiropractor General Practitioner	Yes	Yes	91%
EULAR-K	Europe	2009	17	New	Knee	Doctors Allied health professions	General Practitioner Rheumatologist	Yes	Yes	57%
EULAR-H	Europe	2008	21	New	Hand	Unclear	Unclear	Yes	Yes	56%
EULAR-PJ	Europe	2017	13	New	Multiple joint	Doctors Allied health professions	General Practitioner Rheumatologist Orthopaedic surgeon Radiologist Physiotherapist	Yes	Yes	69%

EULAR/ EFORT	Europe	2010	15	New	Knee	Doctors Allied health professions	General Practitioner Rheumatologist Orthopaedic surgeon Emergency doctor	Yes	No	31%
RACGP	Australia	2009	14	New	Multiple joint	Doctors Allied health professions	General Practitioner	Yes	Yes	75%
APTA	United States	2017	17	Updated	Hip	Doctors Allied health professions	Rehabilitation Specialist	Yes	Yes	84%
VA/DOD	United States	2014	26	New	Multiple joint	Doctors	General Practitioner	No	Yes	83%
NICE	United Kingdom	2014	20	Updated	Multiple joint	Doctors Allied health professions Patients	Unclear	yes	Yes	74%

SIR	Italy	2019	10	Adapted	Multiple joint	Doctors Allied health professions Patients	General Practitioner Rheumatologist Orthopaedic surgeon Rehabilitation specialist Internal medicine Geriatrician	Yes	Yes	68%
RCR	United Kingdom	2017	Unknown	Updated	Multiple joint	Doctors Allied health professions Patients	General Practitioner Radiologist Emergency doctor	No	Yes	39%

MaHTAS: Clinical practice guideline: management of OA, **DIG:** Diagnostic imaging guideline for musculoskeletal complains in adults- an evidence-based approach-part 2: upper extremity disorder, **EULAR-K**: Evidence based recommendations for the diagnosis of knee OA, **EULAR-H:** Evidence-Based Recommendations for the Diagnosis of Hand OA: report of a task force of ESCISIT, **EULAR-PJ**: EULAR recommendations for the use of imaging in the clinical management of peripheral joint OA, **EULAR/EFFORT:** EULAR/EFORT recommendations for the diagnosis and initial management of patients with acute or recent onset swelling, **ACR-F:** Appropriateness criteria: chronic foot pain, **ACR-K**: Appropriateness criteria: chronic knee pain, **ACR-W:** Appropriateness criteria: chronic wrist pain, **ACR-H:** Appropriateness criteria: chronic hip pain, **ACR-EJP**: Appropriateness criteria chronic extremity joint pain: suspected inflammatory arthritis, **ACR-A:** Appropriateness criteria: chronic ankle pain, **RACGP**: Clinical Practice Guideline for the Non-surgical Management of Hip and Knee, **APTA:** Hip Pain and Mobility Deficits-Hip OA: Revision 2017, **VA/DOD**: The Non-Surgical Management of Hip & Knee OA, **NICE:** Osteoarthritis: Care and Management, **SIR:** The Italian Society for Rheumatology clinical practice guidelines for the diagnosis and management of knee, hip and hand osteoarthritis., **RCR**: iRefer: Making the best use of Clinical Radiology

3.3.3 Critical appraisal

CHB and KT independently appraised each guideline against the 23 AGREE II criteria. The percentage agreement between KT and CHB was 86%. The critical appraisal scores for each guideline can be found in Appendix 4 and the weighted score for each domain can be found in Appendix 5.

The RCR guideline is an encyclopaedia of radiology referral recommendations for imaging across all body systems. Due to its broad scope, it did not extensively detail how the recommendations were developed, who was involved, and how evidence was used to inform their recommendations. The low RCR guideline AGREE II score is therefore perhaps a reflection of a lack of transparency, rather than a lack of guideline quality.

Similarly, due to limits on institutional access, it was not possible to obtain all supplementary material documents for the "EULAR evidence-based recommendations for the diagnosis of knee osteoarthritis" (EULAR-K) and the EULAR-H guidelines. This supplementary material included detailed information on the search strategy and reported how evidence was used to inform a recommendation. CHB requested the supplementary material from the 1st author. As these documents were already published, this decision did not contravene my previous decision to not acquire unpublished material. Unfortunately, no reply was received. The critical appraisal of these guidelines is limited by the inability to access the supplementary material.

On average guidelines scored highest on the scope and purpose domain (87%), followed by the clarity of presentation domain (83%). The rigour of development (69%), editorial independence (69%), and stakeholder involvement (66%) domains were similarly well addressed. However, the applicability domain was poorly addressed by most guidelines (32%). As sixteen of the eighteen guidelines had a rigour of development score greater than 50%, they were considered high quality guidelines. "The EULAR/EFFORT recommendations for the diagnosis and initial management of patients with acute or recent onset swelling of the knee" (EULAR/EFFORT) and the RCR guidelines had a rigour score less than 50%. No guideline outperformed the other

guidelines across all domains (Table 3-5). The “Clinical Practice Guideline for the Non-surgical Management of Hip and Knee” (RACGP), “Osteoarthritis: Care and management” (NICE) and “Hip Pain and Mobility Deficits-Hip OA: Revision 2017” (APTA) on average scored the highest across all domains whilst the RCR and the EULAR/EFFORT guideline scored the lowest across all domains. A summary of the scaled domain scores can be found in Figure 3-2.

Table 3-5: The highest scoring guideline for each of the AGREE II domains	
Domain	**Guideline which scored the highest**
Scope and purpose	RACGP NICE VA/DOD
Stakeholder involvement	RACGP NICE
Clarity of presentation	EULAR-K RACGP APTA
Rigour of development	DIG
Applicability	NICE
Editorial independence	APTA ACR-A ACR-F ACR-EJP ACR-W ACR-H ACR-K

RACGP: Clinical practice guideline for the non-surgical management of hip and knee,

NICE: Osteoarthritis care and management,

VA/DOD: The non-surgical management of hip and knee OA,

EULAR-K: Evidence based recommendations for the diagnosis of knee,

APTA: Hip pain and mobility deficits-hip OA: revisions 2017,

DIG: Diagnostic imaging guidelines for musculoskeletal complaints in adults- an evidence-based approach-part 2: upper extremity disorders,

ACR-A: Appropriateness criteria: chronic ankle pain,

ACR-F: Appropriateness criteria: chronic foot pain,

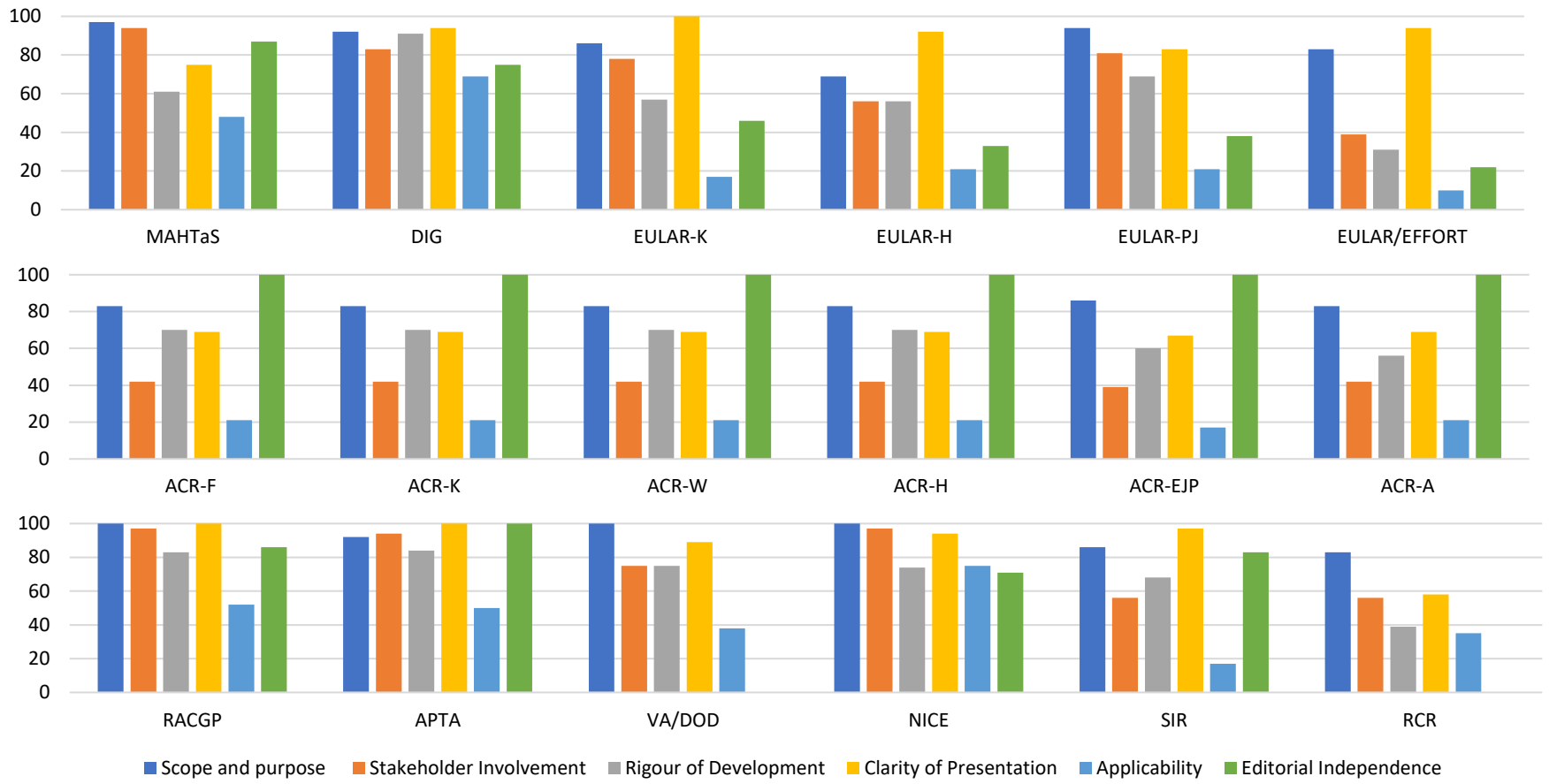
ACR-EJP: Appropriateness criteria: chronic extremity joint pain- suspected inflammatory arthritis,

ACR-W: Appropriateness criteria: chronic wrist pain,

ACR-H: Appropriateness criteria: chronic hip pain,

ACR-K: Appropriateness criteria: chronic knee pain.

Figure 3-3: A bar chart outlining the AGREE II domain scores for each osteoarthritis diagnostic guidelines



MaHTAS: Clinical practice guideline: management of OA, **DIG:** Diagnostic imaging guideline for musculoskeletal complains in adults- an evidence-based approach-part 2: upper extremity disorder, **EULAR-K**: Evidence based recommendations for the diagnosis of knee OA, **EULAR-H:** Evidence-Based Recommendations for the Diagnosis of Hand OA: report of a task force of ESCISIT, **EULAR-PJ**: EULAR recommendations for the use of imaging in the clinical management of peripheral joint OA, **EULAR/EFFORT:** EULAR/EFORT recommendations for the diagnosis and initial management of patients with acute or recent onset swelling, **ACR-F:** Appropriateness criteria: chronic foot pain, **ACR-K**: Appropriateness criteria: chronic knee pain, **ACR-W:** Appropriateness criteria: chronic wrist pain, **ACR-H:** Appropriateness criteria: chronic hip pain, **ACR-EJP**: Appropriateness criteria chronic extremity joint pain: suspected inflammatory arthritis, **ACR-A:** Appropriateness criteria: chronic ankle pain, **RACGP**: Clinical Practice Guideline for the Non-surgical Management of Hip and Knee, **APTA:** Hip Pain and Mobility Deficits-Hip OA: Revision 2017, **VA/DOD**: The Non-Surgical Management of Hip & Knee OA, **NICE:** Osteoarthritis: Care and Management, **SIR:** The Italian Society for Rheumatology clinical practice guidelines for the diagnosis and management of knee, hip and hand osteoarthritis., **RCR**: iRefer: Making the best use of Clinical Radiology

3.3.4 Narrative synthesis

The narrative synthesis of the diagnostic recommendations for OA are presented below under the following themes: risk factors, symptoms and signs, diagnostic recommendations, and imaging recommendations. Specific guideline recommendations can be found in Appendix 6.

Risk factors

Alongside manifestations of OA, risk factors such as older age, female sex and obesity can act as diagnostic indicators whose presence is associated with a higher probability of OA being present (Vina & Kwoh, 2018). Awareness of risk factors can therefore improve diagnostic certainty. However, of the 18 guidelines included in this review, only eight detailed a list of potential risk factors for OA. These guidelines were predominantly targeted at general practitioners. Of the seven radiology guidelines, only the RCR guidelines reported risk factors for OA.

Modifiable risk factors

Few guidelines highlighted potentially modifiable risk factors. Obesity was the most reported modifiable risk factor, as it was reported in six guidelines. Occupational or recreational usage of a joint was reported in five guidelines. Similarly, the impact of malalignment was discussed in five guidelines.

Non-modifiable risk factors

Non-modifiable risk factors were more extensively covered in guidelines. Seven guidelines agreed that joint injury was a risk factor for OA. Equally, seven guidelines identified age as a risk factor for OA, however there was slight variation in the cut off reported. EULAR-H and "The Italian Society for Rheumatology clinical practice guideline for the diagnosis and management of knee, hip and hand osteoarthritis" (SIR) indicated that if a person was ≥ 40 years of age they were at an increased risk of developing OA. RCR and NICE had a slightly older cut off, identifying those ≥45 years of age as being at an increased risk of OA. EULAR-K and APTA further still reported a higher

cut off, specifying those ≥50 years of age as resulting in an increased risk of OA. The "Diagnostic imaging guidelines for musculoskeletal complaints in adults- an evidence-based approach-part 2: upper extremity disorders" (DIG) guideline stated that >50 years of age increased the risk of wrist OA and >60 years of age increased the risk of shoulder OA.

Five guidelines addressed sex as a risk factor for OA. NICE and the "Clinical practice guideline: management of OA" (MaHTAS) report being female as a risk factor for OA; EULAR-H and EULAR-K specifically indicate that female sex is a risk factor for hand OA and knee OA, respectively. APTA, a hip OA guideline, was the only guideline to suggest being male was a risk factor for OA. Of the four guidelines that identified being female as a risk factor for OA, two report a post-menopausal status as increasing the risk of OA.

Symptoms and Signs

No guidelines produced by an organisation representing radiologists extensively discussed the typical symptom and signs of OA. Nine of the eighteen guidelines specifically mentioned joint pain, stiffness, swelling, crepitations, and reduced range of movement as clinical features of OA.

The degree of joint stiffness varied between joint sites. The multiple joint OA guidelines NICE, MaHTAS, and "The Non-Surgical Management of Hip & Knee OA" (VA/DOD) suggested joint stiffness should last less than 30 minutes. The hip OA guideline, APTA, suggested joint stiffness should last less than one hour. Comparatively, EULAR-H reported that joint stiffness in the hand is often mild.

Similarly, the description of pain varied between guidelines. Seven guidelines reported that OA pain was activity dependent. Four guidelines indicated that pain could be intermittent and variable. The DIG guideline suggested that OA pain progresses, whereas the EULAR-K guidelines suggests OA is slow to change. The SIR and EULAR-K guidelines indicate that as the severity of OA increases, patients suffer more rest and night pain. The multiple joint OA guidelines MaHTAS, DIG and VA/DOD suggested that joint pain can be elicited through the compression of the joint line

but only the MaHTAS and DIG guidelines indicated that OA pain is relieved by rest. The EULAR-K guideline suggested OA was worse at the end of the day and the DIG guideline suggested OA pain is resistant to steroid and NSAIDS.

APTA and EULAR-H described joint pain at specific joint sites. APTA reported that in hip OA, patients suffer with lateral hip pain on weight bearing. EULAR-H described specific sites of hand joint pain including the distal interphalangeal joint, the proximal interphalangeal joint, the thumb base, and the middle metacarpophalangeal joint.

Other clinical features specific to joint sites were reported in the guidelines. APTA reported a lack of internal rotation, and weakness of surrounding muscles for hip OA. EULAR-K reported an association between knee OA and a varus or valgus deformity and pain on patellofemoral compression. Hand OA showed the most extensive specific clinical features. EULAR-H reported Bouchard's nodes in the proximal interphalangeal joints and Heberden's nodes in the distal interphalangeal joints. Other hand joint features included lateral deviation of the interphalangeal joints, and subluxation, and adduction of thumb base. EULAR-H and ACR-H identified erosive hand OA as distinct from non-erosive hand OA. EULAR-H described symptoms of erosive OA as pain, redness, paraesthesia, soft tissue swelling and stiffness.

Diagnosis

NICE was the only guideline that produced multiple joint OA diagnostic criteria. MaHTAS published joint specific criteria for the hip, knee, and hand. APTA also published hip OA criteria EULAR-K published knee OA criteria, and EULAR-H published hand OA criteria. The DIG was the only guideline to publish wrist and shoulder diagnostic OA criteria. The diagnostic criteria reported are summarised in Table 3-6.

Table 3-6: The osteoarthritis clinical diagnostic criteria			
Site	**Guideline**	**Diagnostic Criteria**	**Radiographic/ Clinical/ laboratory/ Combined**
Multiple joint	NICE	Diagnose osteoarthritis clinically without investigation if a person: • Is 45 years or over **and** • Has activity related joint pain **and** • Has either no morning joint-related stiffness or morning stiffness that lasts no longer than 30 minutes	Clinical
Hip	MaHTAS	American College of Rheumatology 1991 Criteria Must have hip pain + at least 2 from 3 of the following 1. Femoral and acetabular osteophytes on X-ray 2. Axial joint space narrowing on X-ray 3. ESR <20 mm/hr	Combined clinical, radiographic and laboratory
	APTA	• >50 years of age **and** • Moderate anterior or lateral hip pain during weight bearing activities **and** • Morning stiffness less than 1-hour duration after wakening **and** • Hip internal rotation range of motion less than 24 degrees **or** • Internal rotation and hip flexion 15 degrees less than non-painful side **and/or** • Increased hip pain associated with passive hip internal rotation	Clinical

Knee	MaHTAS	American College of Rheumatology 1986 Criteria: Knee pain + At least 3 of 6 of the following: 1. Age >50 years 2. Stiffness <30 min 3. Crepitus 4. Bony tenderness 5. Bony enlargement 6. No palpable warmth	Clinical
		American College of Rheumatology 1986 Criteria: • Knee pain **and** • Osteophytes on X-ray **and** ○ At least 1 of 3 of the following 1. Age >50 years **or** 2. Stiffness <30 min **or** 3. Crepitus	Clinical and radiographic

		American College of Rheumatology 1986 Criteria: • Knee pain **and** • At least 5 of 9 of the following 1. Age >50 years 2. Stiffness <30 min 3. Crepitus 4. Bony tenderness 5. Bony enlargement 6. No palpable warmth 7. ESR <40 8. Rheumatoid factor <1:40 9. Synovial fluid signs of OA ▪ Clear ▪ Viscous ▪ White blood cell count <2000/mm^3	Clinical and Laboratory
	EULAR-K	• Adults aged >40 years **and** • Usage-related knee pain **and** • Short-lived morning stiffness **and** • Functional limitation **and at least one of** • Crepitus **and/or** • Restricted bone movement **and/or** • Bony enlargement	Clinical

Hand	MaHTAS	American College of Rheumatology 1990 Criteria:
		• Hand pain, aching or stiffness **and**
		• Hard tissue enlargement of ≥2 of 10 selected joint
		  ○ 2nd and 3rd distal interphalangeal joints
		  ○ 2nd and 3rd proximal interphalangeal joint
		  ○ 1stcarpometacarpal joint of both hands
		• **and at least one of the following two**
		• Fewer than 3 swollen MCP joint **and either**
		• Hard tissue enlargement of ≥ of distal interphalangeal joint **or**
		• Deformity of ≥ 2 of 10 selected joints
			Clinical

	EULAR-H	• >40 years old
		Intermittent symptoms of
		  • Pain on usage
		  • Mild morning or inactivity stiffness
		affecting the
		  • Distal interphalangeal joints, proximal interphalangeal joints, thumb base, 2nd, and 3rd metacarpophalangeal joint
			Clinical

Shoulder	DIG	• >60 years old **and** • Progressive pain **and** • Crepitus **and** • Decreased end-ROM **and** • Tender joint	Clinical

Wrist	DIG	• >50 years old **and** • Morning stiffness <30 mins **and** • Crepitations **and** • Bony tenderness **and** • Bony enlargement **and** • No palpable warmth	Clinical

MaHTAS: Clinical practice guideline: management of OA, **DIG:** Diagnostic imaging guideline for musculoskeletal complains in adults- an evidence-based approach-part 2: upper extremity disorder, **EULAR-K**: Evidence based recommendations for the diagnosis of knee OA, **EULAR-H:** Evidence-Based Recommendations for the Diagnosis of Hand OA: report of a task force of ESCISIT, **APTA:** Hip Pain and Mobility Deficits-Hip OA: Revision 2017, **NICE**: Osteoarthritis: Care and Management

Imaging

Six multiple joint OA guidelines suggested an OA diagnosis should be made clinically (Table 3-7). The EULAR-H guideline suggests hand OA should be diagnosed clinically. The RCR guideline and EULAR-K guideline both agreed that OA of the knee should be diagnosed clinically. However, whilst the APTA guideline suggest OA of the hip should be diagnosed clinically, the RCR guideline encourages a radiographic diagnosis for hip OA. Only one organisation representing radiologists recommended a clinical diagnosis of OA.

Although in total 11 guidelines indicated a preference towards a clinical diagnosis of OA, only the NICE, RACGP and the "EULAR recommendations for the use of imaging in the clinical management of peripheral joint osteoarthritis" (EULAR-PJ) guideline explicitly discouraged routine radiography. Seven guidelines advised that radiographic features do not correlate well with symptoms. Four guidelines state that radiographic features do not predict non-surgical treatment response but the RCR guideline indicates that imaging may be useful when referring patients for joint replacements.

All guidelines identified that the first line imaging modality should be radiography. MaHTAS, SIR and APTA indicate that X-rays can be used to assess disease severity whereas NICE guideline indicates that a full holistic background assessment is likely to indicate disease severity greater than radiography.

All six American College of Radiology guidelines describe X-rays as usually appropriate for OA. The RCR guideline described imaging as appropriate in non-traumatic hip pain or arthropathy of the hands and feet. The MaHTAS guideline indicates that X-rays are useful for differentiating between different types of hand arthritis. The DIG guideline indicates that, for the shoulder, radiographs are indicated if pain is unrelieved by four weeks.

Table 3-7: The preferred method of diagnosing OA, and the first line and second line imaging modalities recommended				
Diagnostic preference.	Clinical/ radiographic	Multiple joint	• Clinical with radiograph as an adjunct.	• MaHTAS • EULAR PJ • VA/DOD • NICE • SIR • RACGP • DIG
		Knee	• Clinical with radiograph as an adjunct.	• RCR • EULAR-K
			• Clinical and radiographic	• ACR-K
		Hip	• Clinical with radiograph as an adjunct.	• APTA • ACR-H
			• Clinical and radiographic	• RCR
		Hand	• Clinical with radiographs as an adjunct	• EULAR-H
			• Clinical and radiographic	• ACR-H • ACR-EJP
		Wrist	• Clinical and radiographic	• ACR-W
		Foot	• Clinical and radiographic	• ACR-F
		Ankle	• Clinical and radiographic	• ACR-A

Imaging	First line imaging	Multiple joint	• X-ray	• MaHTAS • EULAR-PJ • RACGP • SIR • RCR • APTA • ACR-H • ACR-F • ACR-A • ACR-W • ACR-K • ACR-EJP • EULAR-H • EULAR-K • VA/DOD • EULAR/EFFORT • NICE • DIG
	Secondary imaging modalities	Multiple joint	• MRI may be appropriate	• RCR • SIR • EULAR-PJ • ACR-H • ACR-W • ACR-K • ACR-F • ACR-A • ACR-EJP

			• Ultrasound may be appropriate	• RCR • SIR • EULAR-PJ • ACR-F • ACR-EJP • MaHTAS
			• CT may be appropriate	• RCR • SIR • EULAR-PJ • ACR-H • ACR-K • ACR-A • ACR-EJP
MaHTAS: Clinical practice guideline: management of OA, **DIG:** Diagnostic imaging guideline for musculoskeletal complains in adults- an evidence-based approach-part 2: upper extremity disorder, **EULAR-K**: Evidence based recommendations for the diagnosis of knee OA, **EULAR-H:** Evidence-Based Recommendations for the Diagnosis of Hand OA: report of a task force of ESCISIT, **EULAR-PJ**: EULAR recommendations for the use of imaging in the clinical management of peripheral joint OA, **EULAR/EFFORT:** EULAR/EFORT recommendations for the diagnosis and initial management of patients with acute or recent onset swelling, **ACR-F:** Appropriateness criteria: chronic foot pain, **ACR-K**: Appropriateness criteria: chronic knee pain, **ACR-W:** Appropriateness criteria: chronic wrist pain, **ACR-H:** Appropriateness criteria: chronic hip pain, **ACR-EJP**: Appropriateness criteria chronic extremity joint pain: suspected inflammatory arthritis, **ACR-A:** Appropriateness criteria: chronic ankle pain, **RACGP**: Clinical Practice Guideline for the Non-surgical Management of Hip and Knee, **APTA:** Hip Pain and Mobility Deficits-Hip OA: Revision 2017, **VA/DOD**: The Non-Surgical Management of Hip & Knee OA, **NICE:** Osteoarthritis: Care and Management, **SIR:** The Italian Society for Rheumatology clinical practice guidelines for the diagnosis and management of knee, hip and hand osteoarthritis., **RCR**: iRefer: Making the best use of Clinical Radiology				

Nine guidelines indicate that radiography should be used to confirm OA when a diagnosis is uncertain, two guidelines recommend X-raying when there is a rapid progression in symptoms and two guidelines suggest radiography is important in staging. Eight guidelines described joint space narrowing, osteophytes, subchondral sclerosis, and subchondral cysts as typical features of OA. The EULAR-H and ACR-EJP identified erosions and ankylosis as specific features of erosive hand OA. ACR-K and EULAR-K additionally identified varus and valgus deformities as common clinical features of knee OA.

Some guidelines did highlight the importance of using specific X-ray views, particularly of taking weight-bearing X-rays in the diagnosis of OA. A summary of the X-ray views recommended can be found in the Appendix 7.

No guidelines recommended the routine use of CT scans or MRI. Nine guidelines suggested MRI is the best modality for assessing soft tissue swelling; six of which were produced by an American organisation and one guideline was produced by an Italian, English, and a multinational European organisation each. Seven guidelines suggested CT is best for assessing bony deformities, of which four were produced by an American organisation, and one by an Italian, English, and a multinational European organisation each. The NICE guidelines indicate however that these modalities are not cost effective enough to be used in routine clinical practice in the UK and the VA/DOD guideline explicitly discourages MRI for OA.

3.3.5 Future research question

Four guidelines posed potential future research questions but only three pertained to the diagnosing of OA. Two guidelines identified a need for research into the accuracy of diagnostic criteria and markers to detect OA earlier. The EULAR-PJ guideline identified a need to determine the cost effectiveness of imaging in clinical practice and its utility in less common OA sites such as the feet. A compiled list of future research questions surrounding the diagnosis of OA has been included in Appendix 8.

3.4 Discussion

3.4.1 Summary of findings.

A comprehensive systematic search identified 18 guidelines which met the selection criteria. Eleven guidelines suggested OA should be diagnosed clinically. Only three guidelines explicitly discouraged the routine use of radiography. One guideline produced by a UK organisation representing radiologists recommended routine radiography for the diagnosis of hip OA. Six American College of Radiology guidelines suggested X-rays are usually appropriate in the diagnosis of OA. All guidelines recommended X-rays as the first line imaging modality. Nine guidelines explicitly stated radiographs as helpful in confirming OA when the diagnosis is uncertain. MaHTAS and SIR recommend radiographs to assess disease severity, whereas EULAR-PJ and RACGP guidelines recommend radiography in patients with a rapid progression of their disease. Nine guidelines identified MRI as the most sensitive modality at detecting soft tissue swelling; six of which were published in United States and two had potential UK jurisdiction. Seven guidelines suggested CT is the most sensitive at detecting bony deformities, of which four were produced by American organisations and two had potential UK jurisdiction.

3.4.2 Comparison with existing literature

This systematic review improves the understanding of the quality and consistency of guideline recommendations with respect to the use of radiography in the diagnosis of OA. The majority of existing systematic reviews concentrate on OA management (Pencharz *et al.*, 2001; Zhang *et al.*, 2007; Nelson *et al.*, 2014). One systematic review focused on the diagnosis and management of hip and knee OA up to 2005, prior to the publication of several prominent national OA guidelines (Misso *et al.*, 2008)

Guideline development

The systematic review performed by Misso *et al.*(2008) critically appraised guidelines using the AGREE tool (Table 3-8). The current study critically appraised guidelines using the AGREE II tool. The most notable difference between the subsequent edition of the AGREE tool is the

development of a 7-point Likert scale to replace the 4-point Likert scale (Brouwers *et al.*, 2010). As a result, comparisons can be drawn between guideline quality using these two slightly different instruments (Hogeveen *et al.*, 2012). However, the subjective nature of critical appraisal tools means that any comparisons should be interpreted with caution.

Table 3-8: Comparison in the average AGREE II domain scores between this systematic review and another systematic review which assessed the quality of OA guidelines

Average domain score	AGREE domain score Misso *et al.* (2008)	AGREE II domain score Henry-Blake *et* al. (2020):
Scope and purpose	76%	88%
Clarity of presentation	77%	83%
Stakeholder involvement	35%	66%
Rigour of development	47%	69%
Editorial independence	30%	69%
Applicability	18%	32%

Misso *et al.* (2008) identified poor guideline quality for hip and knee OA. The average rigour of development score in their study was 47%. Comparatively the rigour of development score in the current study was 67%. This may be a result of the slightly different editions of the tools used and how the appraisers used the tools. Furthermore, as the current study contained more contemporary guidelines, it would be tempting to assume this difference reflects a trend of increasing guideline quality over time. However, evidence for the improvement of guideline quality over time is lacking (Kung, Miller & Mackowiak, 2012). Consequently, it is perhaps more likely that the difference in rigour of development scores is a result of different inclusion criteria. The current study only included guidelines based on a systematic review of evidence, but there is no mention of this criterion in the study by Misso *et al.* (2008). As a result, the guidelines in the current study are more likely to be of higher quality which could explain the disparity in rigour of development scores.

Despite potentially different exclusion criteria, parallels can be drawn between the two studies. In both studies, guidelines excelled in the scope and purpose domain and the clarity of

presentation domain; but performed poorly in the applicability domain. This provides further evidence that guidelines continue to lack implementation tools to improve the applicability of their recommendations (Gagliardi & Brouwers, 2015).

Similarly, Misso *et al.* (2008) found that guidelines are largely consistent in their recommendation. This was consistent with the current study as, for example, all the guidelines recommended radiography as the first line imaging modality. As extensive resources are necessary to create guidelines, the duplication of work to create different guideline on the same topic may not be an efficient use of resources (Sox *et al.*, 2008). Furthermore, an abundance of poor-quality guidelines can result in conflicting recommendations and reduced adherence. This uncertainty reduces the ability of clinicians to make their decisions confidently. This prevents guidelines from meeting the quadruple aims (Harrison *et al.*, 2010). To use resources more efficiently, the ADAPTE collaboration have produced a pathway for guideline developers to adapt existing guidelines to their clinical context (Graham *et al.*, 2002). This process involves searching for evidence-based guidelines, screening those guidelines, and then assessing the quality and consistency of their recommendations (ADAPTE, 2009). The guideline developers can then adapt the recommendations to fit the local clinical context. To finalise, an external review process is undertaken which includes patients, practitioners, professional bodies, and translational experts to ensure the guideline is of high quality and implementable. This ADAPTE framework results in more applicable guidelines which improve patient, population and practitioners experience at a cheaper cost, improving the ability of guidelines to meet the Quadruple Aims of healthcare. The current study only identified one guideline that followed the ADAPTE process (Ariani *et al.*, 2019). The Italian Society of Rheumatology used the ADAPTE framework to adapt guidelines produced by the European League Against Rheumatism and the American College of Rheumatology to fit the Italian clinical context (Manara *et al.*, 2019). An additional benefit of the adaptation of guidelines is that they can be tailored to specific clinical contexts, which provides greater scope for the inclusion of implementation strategies to local clinical practice (Misso *et al.*, 2008). This could help drive the improvement of guideline applicability.

In both the creation and adaption of guidelines, it is important to include developers from a wide range of specialities. This is because different stakeholders will have different perceptions as to the relative importance of interventions based on their clinical experience (Rycroft-Malone *et al.*, 2004). This opportunity for discussion may result in a consensus being reached between different stakeholders (Rycroft-Malone *et al.*, 2004). This is even more important when there is an absence of strong evidence, where recommendations rely more on expert opinion (Watine, Wils & Augereau, 2014). This review found guidelines produced by organisations representing radiologists recommended a larger role for radiography when compared to guidelines produced by other organisations. Furthermore, due to a lack of reporting on the stakeholders involved in the American College of Radiology and the Royal College of Radiology guidelines, it is difficult to ascertain which specialities and to what extent they were involved in the guideline development process. Murphy *et al.* (1998) found that developers are more likely to recommend interventions that they are familiar with. If radiologists predominated in the development of these guidelines, it could explain why these guidelines recommend a larger role for radiology in the care of patients with OA. This is even more likely in the context of the lack of high quality evidence confirming or disproving the added diagnostic utility of a radiograph (Wang, Oo & Linklater, 2018). If this is true, this provides further evidence for the necessity of a wide range of stakeholder in guideline development.

However, this finding is confounded by the country of origin of the guidelines. Six of the seven radiological guidelines were produced in America. As a result, the difference in perception as to the role of imaging may reflect a broader difference in health care utilisation (Papanicolas, Woskie & Jha, 2018).

Diagnostic recommendations

Guidelines identified similar clinical features for OA. Of the nine guidelines that reported OA symptoms and signs, all nine identified joint pain, stiffness, swelling, crepitus, and reduced range of movement as important clinical features in OA. These clinical features applied to the hip, knee,

hand, shoulder, and wrist. Only slight variation existed in the diagnostic recommendations across joint site. Similarly, Misso *et al.* (2008) identified similar diagnosis and treatment recommendations for the knee and hip. Peat, Croft & Hay (2001) questioned the importance of assessing OA distinctly based on joint site. They suggested the comparable functional impact and pain management needs made OA across joints more similar than different. The current study provides further evidence that, within clinical practice, OA may be viewed as a homogenous disease, independent of joint site.

GPs report a lack of confidence in diagnosing OA without imaging (Egerton *et al.*, 2018). Diagnostic criteria can improve GPs confidence in their clinical diagnosis. However, twelve of the eighteen guidelines did not include diagnostic criteria for OA. Of those that did report diagnostic criteria, no specific criteria were favoured. Each of the American College of Rheumatology, EULAR, and NICE criteria were only recommended by one guideline organisation. This is surprising, as a study by Skou *et al.* (2020) identified the NICE criteria as the most sensitive criteria to diagnose OA in primary care, followed by the American College of Rheumatology knee criteria and lastly the EULAR knee criteria. This may be explained by the specific objective of each criteria. The NICE criteria was developed for the purpose of diagnosing OA in primary care, whereas the American College of Rheumatology knee criteria was developed for use in secondary care, where advanced disease is frequently managed (Skou *et al.*, 2020). These findings suggest that more guidelines aimed at diagnosing OA in the primary care setting should consider utilising the clinical OA criteria as recommended by NICE.

The role of imaging in OA

Routine radiography does not improve diagnostic certainty in patients with typical clinical features of OA (Skou, Thomsen & Simonsen, 2014; Wang, Oo & Linklater, 2018). This is not reflected in the seven guidelines which argue that radiography is indicated in a typical OA diagnosis. All seven of these guidelines were produced by organisations representing radiologists.

In contrast however, 11 guidelines suggested a clinical diagnosis for OA is preferable. Seven of these guidelines suggested this is because clinical symptoms are not always consistent with radiographic features (Bedson & Croft, 2008). Furthermore, two guidelines reassured practitioners that not X-raying a patient was unlikely to result in serious missed pathology. Despite this, only the NICE guideline, the RACGP guideline and the EULAR-PJ guideline firmly and explicitly discouraged routine radiography. This use of ambiguous and non-specific language has been associated with a reduction in guideline adherence (Grol *et al.*, 1998). Another factor associated with non-adherence to recommendations is long and difficult to read guidelines (Gransjøen *et al.*, 2018). Unfortunately, while clear language was used in those guidelines which explicitly discouraged radiography, they were longer; the NICE guideline was 505 pages long, and the RACGP guideline was 82 pages long. Additionally no summary versions of these guidelines explicitly discouraged routine radiography. The lack of clear and concise recommendations could explain why GPs are suspected of inappropriately using X-rays to diagnose OA (Morgan *et al.*, 1997).

Another factor resulting in non-adherence to guideline recommendations is a fear of medico-legal repercussions (Morgan *et al.*, 1997). However, the liability of not offering radiographs to patients with a typical OA presentation is likely to be low. To establish clinical negligence within the UK, three criteria must be fulfilled (Fearnley, Bell & Bodenham, 2012). Firstly, the patient must be owed a duty of care. Secondly, that duty of care must fall below the medical standard. Thirdly, this must result in some harm to the patient (Fearnley, Bell & Bodenham, 2012). Guidelines have been used in legal cases to represent the standard of care (Fearnley, Bell & Bodenham, 2012). As guidelines produced by general practice organisations recommend a clinical diagnosis for OA, they in theory are offering the medical standard of care. Furthermore, the risk of harm to patients of not offering X-rays is low (Skou, Thomsen & Simonsen, 2014). Consequently, the medico-legal fears harboured by practitioners may be largely unfounded.

Despite the differences in guideline recommendations, all guidelines agreed that when further investigations are necessary, X-rays should be used first line. The evidence for this recommendation ranged from meta-analysis of case control studies (Zhang *et al.*, 2009; Ariani *et al.*, 2019; Zhang *et al.*, 2010) to expert opinions (Royal College of Radiologists, 2017b; Landewé *et al.*, 2010; EULAR *et al.*, 2017; Melorose, Perroy & Careas, 2013). The rationale for utilising X-rays over other imaging modalities is because they are cheap and easy to access (EULAR *et al.*, 2017). Additionally the added diagnostic certainty from MRI and ultrasound does not sufficiently compensate for its expense (Bijlsma, Berenbaum & Lafeber, 2011; Haugen & Hammer, 2014).

When utilising X-rays, guidelines disagreed on which views should be taken (Appendix 7). This reflects the variation of X-ray views recommended in research and regional departments (Bedson & Croft, 2008; Vince, Singhania & Glasgow, 2000). This was identified by the EULAR-PJ guideline as an area which needs further research (EULAR *et al.*, 2017).

Although this systematic review focused on diagnostic guidelines, it did look at the role of imaging in the management of OA. Confusion exists as to the exact role of radiography in the OA management pathway. The EULAR-PJ guideline indicates that X-rays should not be used to monitor patients, whereas the RCR and SIR guidelines state that X-rays are useful in the assessment of OA severity and in preparation for surgery. This inconsistency may reflect the lack of consensus between orthopaedic surgeons as to the role of imaging in the surgical management of OA (Dreinhöfer *et al.*, 2006; Mancuso *et al.*, 1996; Dolin *et al.*, 2003; Quintana *et al.*, 2000). This confusion leads to GPs requesting X-rays for patients as they believe they are necessary for specialist assessments (Morgan *et al.*, 1997). This could partially explain why the rate of X-rays for OA is suspected to be high (Brand *et al.*, 2014).

Finally, guidelines are evidence-based recommendations to fit a particular clinical context. My systematic review identified a limited role for radiography in the diagnosis and management of OA. However, the current guidelines were constructed in the context of face-to-face consultations. The coronavirus pandemic has caused a shift in general practice consultations

from face to face to remote consultations. The applicability of these guidelines, and thus the role of radiography in the remote diagnosis and management of OA is uncertain. As a result, it is important to consider that the limited role for radiography identified in this review may not reflect the potential role for radiography in future remote consultations.

3.4.3 Strengths of the guidelines

Guideline Development

A strength of most of the guidelines is they provided extensive reporting. Eleven guidelines provided detail on how their guideline recommendations were developed, who was involved and how the evidence was used. The only guideline not to provide this information was produced by the American College of Radiology and the Royal College of Radiology. The EULAR-K and EULAR-H guidelines stated they provided this information in the supplementary material. The publication of this methodological material allows for an assessment of guideline quality.

Another strength of the guidelines was the involvement of stakeholders in their development. This review found that all guidelines were developed or externally reviewed by multi-disciplinary teams, however the extent of the multi-disciplinary teams' involvement is unclear. The inclusion of a team of professional from different backgrounds is important as it improves the applicability of guideline recommendations (Murphy *et al.*, 1998).

Guideline implementation

Another strength of the guidelines is that each guideline summarised their recommendation in an easy to read format. This is beneficial as GPs and radiologists report a barrier to guideline adherences in radiology is guidelines being too long and difficult to read (Gransjøen *et al.*, 2018). Providing a shorter list of recommendations for practitioner may improve guideline adherence.

3.4.4 Limitations of the guidelines

Guideline Development

Most guidelines did not explicitly mention if any resource implications were considered when developing their recommendations. Only the NICE guideline explicitly and extensively discussed cost-effective analysis and economic evaluation papers in the guideline development process. A lack of cost effectiveness analysis in guidelines has been found nationally and internationally, permeating through many common conditions (Garrison Jr, 2016; Brouwers *et al.*, 2010). This information is vital for policy makers who may rely on guidelines to inform their resource allocation.

The two guidelines with a rigour of development score less than 50% were the EULAR/EFFORT guideline and the RCR guideline. The EULAR/EFORT guideline contained a systematic search of the evidence, but none of the evidence was used to form their recommendations. This significantly reduced the quality of the guideline.

The poor rigour of development score for the RCR guideline was likely a result of targeted reporting of guideline development methodology. Little information was provided on the stakeholders involved, the search strategy used and how the evidence informed their recommendations. This is likely a result of the large scope of the guidelines. The RCR guideline provides referral criteria for clinical topics throughout clinical medicine. The breadth of the guideline meant that it is impractical to offer in depth methodological reporting for each section of recommendations. However, the poor methodological reporting is likely reflected in a worse performance across the AGREE II domains.

Similarly, the American College of Radiology only produced one policy document outlining the guideline development methodology, which was published in 2015. The current study identified six American College of Radiology guidelines published from 1998 to 2018. This one policy document means it must be assumed that the same methodology was used in each guideline. It also must be assumed that the methodology published in 2015, was the same methodology used

in 1998. Furthermore, specific details into the guideline development process, such as which stakeholder were involved and details about the external review process are not reported. Therefore, the critical appraisal of the American College of Radiology guidelines should be treated with caution.

Guideline implementation

Implementing evidence-based recommendations effectively may be improved through high quality audit and feedback (Hysong, Best & Pugh, 2006; Davis & Taylor-Vaisey, 1997). Guidelines can promote this strategy by producing their own audit criteria. However, within this systematic review, only two guidelines contained audit criteria (Melorose, Perroy & Careas, 2013; NICE, 2014a), and only one of those audit criteria focused on the diagnosis of OA (NICE, 2014a). As OA management has been shown not to follow guidelines (Healey *et al.*, 2018), the lack of audit criteria could indicate a possible intervention which may improve guideline adherence.

3.4.5 Strengths of this review

Firstly, a comprehensive search strategy was undertaken. Other systematic reviews of OA guidelines were limited to those published in peer review journals or limited to the inclusion of guidelines focused on specific joint sites (Kinds *et al.*, 2011; Zhang *et al.*, 2007; Pencharz *et al.*, 2001). However, this study searched six bibliographic databases, four health improvement and guideline databases as well as a hand search of nine professional organisations website for guidelines across all OA sites except the spine and temporo-mandibular joint.

An additional strength is that the screening process involved three reviewers. As each abstract and full text underwent dual screening, this increases the chance of identifying relevant studies (Stoll *et al.*, 2019).

Another advantage of this systematic review is that it is novel. This systematic review examined the role of radiography in the diagnosis of OA, with a secondary aim of synthesising diagnostic recommendations across all OA sites except the spine and temporo-mandibular joint. Other

systematic reviews have focused on management of OA at specific sites. (Kinds *et al.*, 2011; Zhang *et al.*, 2007; Pencharz *et al.*, 2001) or the diagnosis of OA but only at the hip or knee (Misso *et al.*, 2008).

3.4.6 Limitations of this systematic review

Limitations of this review can be considered within the screening, critical appraisal, and data extraction processes.

Screening

Although a comprehensive search was undertaken, only guidelines written in English were included in this review. As a result, the guidelines included in this review are disproportionately published in Europe and America and do not represent the global recommendations surrounding the diagnosis of OA.

Furthermore, for five guidelines, despite Institutional access provided through Keele University and NHS OpenAthens, the full text was not available for screening to determine if the article matched the selection criteria. This may be due to these titles and abstracts being uploaded on to core medical databases as conference presentation or proceedings, and consequently lack a corresponding full text.

Critical appraisal

Observer-expectancy bias may have arisen in the critical appraisal of the guidelines, as both appraisers were most familiar with the NICE guidelines. Due to their more frequent use, it is possible that the researchers expected these guidelines to be of higher quality, and as a result interpreted the guidelines to confirm their preconceived bias.

Data extraction

Finally, a limitation in the data extraction process was that only one individual undertook the data extraction of the guidelines. The second reviewer assessed the fields to look for any missing

data. Single data extraction has been found to generate more errors than dual data extraction (Buscemi *et al.*, 2006). It is possible this could have resulted in missed recommendations.

3.5 Conclusion

Eleven guidelines suggested a clinical OA diagnosis is preferable; only three guidelines explicitly discouraged routine radiography. No guidelines recommended the routine use of MRI or CT, despite recognising their superior sensitivity in detecting structural changes attributable to OA. Although the quality of guideline development was high, little emphasis was placed on cost-effective analysis, resource implications and implementation strategies. Due to the high overlap between guidelines on recommendation, and the extensive resources used in guideline development, more guideline organisations should consider adapting pre-existing guidelines to fit their local clinical context. The next chapter will estimate the trends and determinants of the use of X-rays in OA within primary care.

4 Trends and determinants of the use of radiography for osteoarthritis

4.1 Introduction

The systematic review found that guidelines produced by organisations representing general practitioners did not recommend routine radiography to confirm a clinical diagnosis of OA. However, only the NICE, RACGP and EULAR-PJ guidelines explicitly discouraged the routine use of radiography for OA.

This chapter aims to investigate trends in the use of radiography for OA and the potential impact of guideline publications on X-ray use.

4.2 Objectives

- Estimate the proportion of patients presenting to general practice with OA in whom an X-ray is requested, and changes in this proportion during the period 2000-2015
- Explore whether any changes over time in the above proportion coincided with the publication of relevant NICE and RCR guidelines.
- Estimate the proportion of patients who are referred to secondary care following an X-ray request for OA, and changes in this proportion during the period 2000-2015
- Estimate the direction and magnitude of association between measured patient characteristics and the likelihood of an X-ray being requested for OA.
- Explore the extent of variability between general practices in the proportion of patients with OA in whom an X-ray is requested

4.3 Estimating health-care utilisation

Two broad sources of data are frequently used to assess health care utilisation: patient self-report data and routinely collected electronic health records (EHRs) (Wallace *et al.*, 2018). These sources of data and their advantages and disadvantages are described below.

4.3.1 Patient self-report data

Patient self-report data are often collected through patients answering standardised questions in the format of surveys, interviews or questionnaires (Althubaiti, 2016). An advantage of self-report data is that, if standardised, all patients are asked the same questions, in the same way, which reduces the interference a researcher may have (Althubaiti, 2016). Uniquely, self-report data is able to measure the use of non-medical resources which are not routinely recorded on EHRs (Goossens *et al.*, 2000).

There are several disadvantages to patient self-report data. Patient self-report data is susceptible to recall bias (Althubaiti, 2016; Jordan, Jinks & Croft, 2006). Recall bias is a form of information bias whereby patients omit or mis-remember events, especially events which are insignificant or events which occurred a long time ago (Althubaiti, 2016). Patient self-report data would have been unsuitable for this study as patient recall of X-rays has been found to be poor (Haapanen *et al.*, 1997). Furthermore, this study sought to examine the trend in X-ray requests over a 16-year period. This long recall period could result in telescoping, whereby patients misremember the date at which an event occurred (Martin, 2006). This could introduce inaccuracies into the trend estimate.

Patient self-report data is also susceptible to non-response bias (Korkeila *et al.*, 2001). This is a form of selection bias, whereby respondents systematically differ from non-respondents. If the characteristics of the non-respondents is associated with the outcome, this can distort estimations of association (Tripepi *et al.*, 2010). Specific factors associated with non-response bias in surveys assessing OA in the North Staffordshire population include gender and age; these are factors that this study aims to assess (Thomas *et al.*, 2004).

Finally, the production of patient self-report data is resource intensive. It takes a large amount of time and money for researchers and ethics committees to construct and distribute large population surveys (Franklin & Thorn, 2019). Furthermore, it is burdensome on patients, as they must take time to answer questionnaires (Franklin & Thorn, 2019). Collection of patient self-

report data was considered unsuitable for this research project due to the level of resource that would have been required, in comparison to the use of an existing dataset.

4.3.2 Electronic health records

What are electronic health records

As described in the background chapter, EHRs are a store of routinely collected data, recording the interaction between the patient and the health care service (Agniel, Kohane & Weber, 2018). This data is recorded as a mixture of free text and Read codes (Verheij *et al.*, 2018). Read codes are an agreed set of hierarchical codes that represent clinical information (Benson, 2011). A sample of the primary care populations EHRs can be pseudo anonymised and uploaded to primary care databases, which can be accessed for epidemiology research, audit and planning (Verheij *et al.*, 2018). Examples of their use includes in the estimation of the utilisation of prescription drugs (Bedson *et al.*, 2016; Appleyard *et al.*, 2019).

The Consultations in Primary Care Archive (CiPCA) has been used to assess health care utilisation (Bedson *et al.*, 2016). The CiPCA database compiles EHRs from nine general practices in the North Staffordshire area. The practices have a research agreement with the School of Primary, Community, and Social Care at Keele University which meant they were accessible for this research project.

An alternative database which could have been used is the CPRD database (Herrett *et al.*, 2015). This is a large national general practice database which contains routinely collected electronic health record data with linked secondary care data. One advantage of CPRD is that it is a larger dataset, covering a large geographic area. As a result, it is likely to be more representative of X-ray use. Additionally, the broader geographic coverage could allow for regional comparisons to be made. Furthermore, this larger dataset would provide more data to test the association between a patient characteristic and the likelihood of receiving an X-ray for OA, reducing the range of confidence intervals and the likelihood of a type 2 error. However, due to the increased cost of access compared to the CiPCA database, the length of time to gain access to the dataset

and the complexities of analysing a dataset of this size, the use of CPRD was deemed unfeasible for this MPhil thesis.

Advantages

An advantage of EHRs is their coverage. 95% of the general population are registered to a general practice (Jordan *et al.*, 2006). As most patients potentially have an EHR, if the population is sampled representatively for the condition studied, there is a reduced risk of selection bias. However, discrepancies exist between what patients present to their general practitioners for, and what conditions GPs code (Jordan *et al.*, 2006). A patient may present to their GP with several conditions, and only those conditions the GP feels are important may be coded (Jordan, Jinks & Croft, 2006). This is speculated to contribute to the under-recording of OA within primary care (Yu, Jordan & Peat, 2018).

An additional advantage of EHRs is the potentially wide-ranging data that can be collected. Social information, disease history, examination findings, diagnoses, investigations, referrals and treatments can be collected prospectively on a patient from "cradle to grave" (Jordan *et al.*, 2006). Utilising this data, the frequency of diseases and the relationship between time and the determinants and distribution of disease can be estimated (Scherrer & Pace, 2017).

Disadvantages

However, currently the use of EHRs has several disadvantages. The collection and coding of some data, including X-ray data, is not incentivised or mandatory (Bradley, Lawrence & Carder, 2018). This leads to variability in the completeness of data between practices and practitioners. This lack of stability can also lead to variation in coding practices over time, which can introduce inaccuracies when assessing trends in health care utilisation (Yu, Jordan & Peat, 2018).

Another disadvantage of EHRs is the potential for the misclassification of cases. Due to the extensive library of Read codes, practitioners may use a wide range of different codes to represent the same clinical concept. For example the Read codes associated with diagnostic OA are less commonly used to describe OA than the Read codes associated with joint pain (Jordan *et*

al., 2016). If the Read codes are missed when extracting data from these databases, this may result in systematically neglected data, which can introduce bias (Yu, Jordan & Peat, 2018).

Another limitation of EHRs in assessing health care utilisation is the absence of data linking an event with a morbidity or consultation code. When assessing the utilisation of X-rays, researchers have to assume that an X-ray of a relevant joint temporally related to an OA consultation is a direct result of the OA consultation (Yu *et al.*, 2017). This assumption could introduce inaccuracies when identifying cases and is thus a disadvantage of using EHRs when assessing health care utilisation.

Finally, consultation data is downloaded from practices periodically. For example, within the CiPCA database, data was only available from 2000-2015. This delay in data extraction can limit the ability of EHRs to answer contemporary research question (Franklin & Thorn, 2019). Despite these disadvantages, EHR data were deemed the most suitable for the current study.

4.4 Methods

4.4.1 Study design

This study utilised prospectively collected data from nine CiPCA research general practices in the North Staffordshire area from January 2000 to December 2015. From this sampling frame, the population of people with a recorded OA consultation was selected.

4.4.2 Osteoarthritis population

The OA population is defined as any patient ≥45 years of age who consulted and had one or more clinical OA Read codes recorded between 2000-2015. The Read codes were taken from an established Read code list produced by six experienced clinicians (Jordan *et al.*, 2016, 2014; Yu *et al.*, 2017). The Read code list is available from www.keele.ac.uk/mrr and can be found at Appendix 9. This study defined "clinical OA" as OA diagnostic Read codes or joint pain Read codes in a patient ≥45 years of age. Patients with joint pain Read codes were included as these Read codes have been associated with earlier symptoms and signs of OA (Jordan *et al.*, 2016). Furthermore, by not including joint pain Read codes I would be likely to miss patients with OA. This is consistent with Yu, Jordan & Peat (2018) who sought to understand how OA is recorded in general practice. 95% of total knee replacements are performed for OA. As a result, Yu, Jordan & Peat (2018) retrospectively identified the Read codes recorded on patients EHRs within 3 years of a total knee replacement. A recorded diagnostic OA Read code was found in 34.7% of patients, which increased to 71.6% when they additionally searched for joint pain Read codes; this illustrated the necessity of including joint pain Read codes to reduce the risk of systematically neglected data. However this broader definition is more likely to capture other forms of arthropathy. To further exclude non-OA cases, an age discriminator of ≥45 years of age was added, as this is the cut off recommended by NICE and will therefore be most relevant to UK general practice (NICE, 2014a). Furthermore, this OA population definition has been validated in other studies (Yu, Jordan & Peat, 2018; Yu *et al.*, 2017).

4.4.3 Outcomes of interest

Proportion of patients in whom an X-ray was requested for their OA

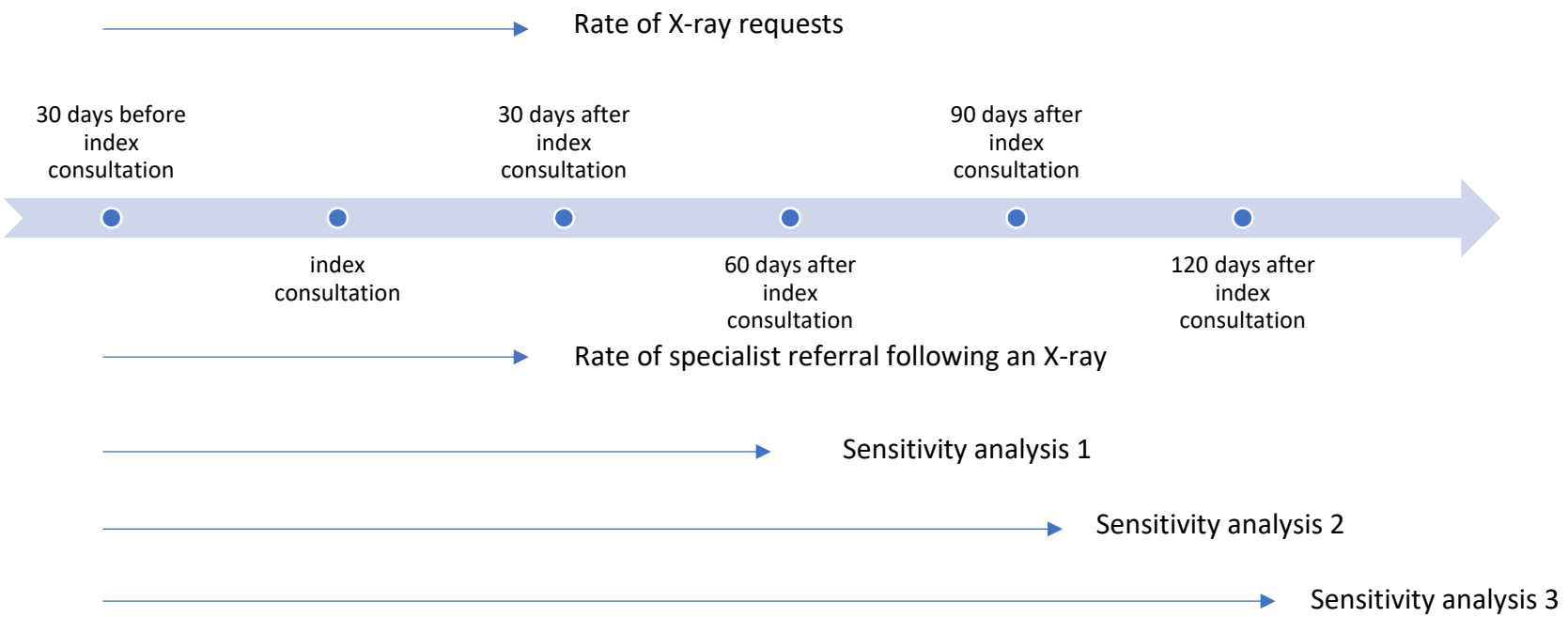
This outcome is defined as individuals ≥45 years of age, with a recorded X-ray Read code within 30 days either side of a clinical OA Read code (Figure 4-1). Due to the possibility of an X-ray result being used to inform a subsequent consultation for clinical OA, it was recognised that a window of time either side of a clinical OA consultation may contain a relevant X-ray result pertinent to that consultation. Restricting the window period to 30 days before and after the clinical OA consultation improved my confidence that the X-ray request was temporally linked to the OA consultation and likely to be relevant to that consultation. This definition is consistent with Yu *et al.* (2017).

The X-ray Read code list was developed by CHB using the "Clinical Terminology Browser Version 3" (Appendix 10) and ratified by the CiPCA data manager. The Read code list included those related to the requesting of X-rays for the foot, ankle, knee, hip, wrist, and hand from the "Operations, Procedures, and Investigations" domain. The Read code list also included Read codes associated with X-ray results, found within the "Clinical Findings" domain of the "Clinical Terminology Browser Version 3". Regardless of if the event was counted due to a clinical finding Read code, or an X-ray request Read code, they are described as requests throughout this study. This is because not all patients who received an X-ray request would have attended an X-ray clinic. Read codes related to the spine were not included, as spinal OA literature is often discussed separately to OA at other sites (NICE, 2014b). OA of the shoulder and elbow were not included as these are uncommon sites for OA (Cushnaghan & Dieppe, 1991). OA of the wrist is also an uncommon site, but as examination of the hand may include the assessment of the carpometacarpal joints, an X-ray for hand OA may include a wrist X-ray (Haugen *et al.*, 2011).

This highlights the potential for duplicate recorded X-rays, i.e. requested X-rays and X-ray results, as well as X-rays being requested for OA at multiple sites. If a patient had multiple OA consultations in a month, the first OA consultation was chosen. If a patient had multiple X-rays in

a single month, again only the first X-ray was chosen. When estimating the proportion of patients who received an X-ray request for OA in each calendar year, a patient could only be counted once.

Figure 4-1: The period between the outcome of interest and the index OA consultation



The association between the publications of national OA guidelines and change in the underlying trend in X-ray requests.

I chose to use a joinpoint regression analysis to measure the association between the publication of a national OA guideline, and the trend in X-ray request rates for OA (National Cancer Institute, 2020). This data-driven method assumes that the observed trend data can be divided into linear segments, separated by joinpoints (Kim *et al.*, 2000). The presence of a joinpoint indicates a change in underlying trend. Successive models are tested, each with one extra joinpoint and compared to the previous model up to a defined maximum number of joinpoints. A likelihood ratio test statistic is calculated to assess if the joinpoint model with one extra joinpoint is a better fit to the observed data, using a p-value of 0.05 to test significance. To calculate the trend in X-ray requests for each quarter, estimates were taken for the proportion of patient consulted for OA in whom an X-ray was requested from 2000-2015. The numerator and denominator populations are outlined above. A patient could only be included once per quarter.

Segmented regression is an alternative statistical analysis which measures a change in trend following an intervention (Taljaard *et al.*, 2014). The trend data is split into pre and post intervention segments. Statistical tests can then be used to measure the change in the slope in the pre-intervention period, compared to the post intervention period. The disadvantage of segmented regression when compared to joinpoint regression is that the researcher must impose a specific date at which an intervention would change healthcare behaviour. However, the date at which a guideline changes behaviour may not be the publication date. Draft guidelines released prior to the publication date have the potential to change practitioner behaviour, as do dissemination and implementation strategies which are initiated after the guideline publication date. As a result, if the wrong intervention period is chosen this could result in mistakenly concluding that an intervention had no effect.

Furthermore, the use of joinpoint regression analysis has the potential to highlight changes in behaviour which are not closely temporally-associated with the publication of guidelines. This

could reveal alternative factors which may have had an impact on X-ray request rates. These potential factors could be researched later.

Proportion of patients who received a potentially relevant specialist referral following an X-ray request for OA.

This outcome describes the proportion of the population with a recorded Read code indicating a potentially relevant specialist referral in secondary care, within 30 days either side of an OA consultation, which resulted in an X-ray request. The specialities defined as potentially relevant are found within Table 4-1.

Table 4-1: The potentially relevant specialist referrals following an X-ray for OA

- Orthopaedics
- Rheumatology
- Physiotherapy
- Other:
  Occupational therapist, Orthotist, Chiropodist, Pain clinic, Dietician, Weight management programme, Surgical fitter

Read codes associated with these referral options were extracted from the "Clinical Terminology Browser Version 3" and cross referenced with a Read code list generated by JE, a clinical academic GP (Edwards, 2017). The final Read code list can be found at Appendix 11. If a patient had multiple potentially relevant specialist referrals, only the first referral was counted. A sensitivity analysis was undertaken to assess the impact of changing the time criteria on the proportion of patients that went on to a specialist secondary care referral following an X-ray request for OA (Figure 4-1).

The direction and magnitude of association between potential determinants of OA and the likelihood of an X-ray request for OA

I aimed to estimate the direction and magnitude of association between the likelihood of an X-ray request for OA and the following patient characteristics: sex, ethnicity, index of multiple deprivation, anxiety, depression, and number of OA consultations. I then sought to explore the

variation in X-ray request rates between GP practices. Specific covariates with complex definitions are defined below.

Relative deprivation

The Index of Multiple Deprivation (IMD) forms part of the Indices of Deprivation. Multiple domains are used to calculate the Index of Multiple Deprivation for a neighbourhood (Table 4-2).

Table 4-2 Domains and weighting in English Index of Multiple Deprivation (2015)

Income	22.5%
Employment	22.5%
Health Deprivation and Disability	13.5%
Education, Skills Training	13.5%
Crime	9.3%
Barriers to Housing and Services	9.3%
Living Environment	9.3%

Each neighbourhood can then be ranked nationally to determine their ordinal level of deprivation in England. National rankings were obtained from the English Indices of Deprivation 2015 to group patients into quintiles (Smith *et al.*, 2015).

Anxiety and Depression

This study defined comorbid anxiety or depression as a Read code for these respective conditions within 12 months either side of their first OA consultation. The Read codes for anxiety and depression were developed by four experienced clinicians and have been implemented in other studies utilising the CiPCA database (Chen *et al.*, 2019).The decision to use after-the-event data was made as I believed that due to the chronicity of these condition, patients may have subthreshold anxiety and depression before this was clinically recorded on the patients' EHRs. However, the decision to use a diagnosis of anxiety and depression after the OA consultation could bias our estimates, as the anxiety and depression may lie along the causal pathway, i.e. a diagnosis of OA results in anxiety and depression which impacts the likelihood of receiving an X-ray for OA. This could mean that both OA patients who receive an X-ray, and patients who do not

receive an X-ray, may have anxiety and depression. This could under-estimate the true association between anxiety and depression and the likelihood of an X-ray request for OA.

Multiple consultations

Edwards (2017) found that patients with multiple consultations were more likely to receive an X-ray request for OA. This potential relationship was explored through categorising the frequency of consultations in to four groups: 1-3 consultations, 4-6 consultation, 7-9 consultations and 10 or more consultations across the 15-year study period.

Year of first OA consultation.

The year of first OA consultation is defined as the first recorded clinical OA Read code between 2000-2015. I sought to assess if the year at which a patient has a first recorded clinical OA consultation is associated with the likelihood of an X-ray request for OA.

4.4.4 Protocol development

A study protocol for the analysis was produced by CHB and reviewed by JE, MM, and GP. The protocol was submitted to the CiPCA Academic Custodianship Committee and approved on the 12th March 2020.

4.4.5 Statistical analyses

This thesis utilised two software packages: IBM SPSS Statistics version 24 (IBM, 2016) and Joinpoint Regression Programme 4.7.0.0.(National Cancer Institute, 2020)

Objective 1: Estimate the rate of X-ray requests in patients presenting to general practice with OA, and changes in this proportion during the period 2000-2015

Objective one aimed to estimate the trend in X-ray request rates from 2000-2015. I estimated the proportion of patients who received an X-ray request linked to an OA consultation over a one-year period, across nine GP practices. The numerator was defined as the number of patients ≥45 years of age who had at least one recorded X-ray Read code within 30 days either side of a

clinical OA Read code. The denominator was defined as the number of patients ≥45 years of age who had at least one clinical OA consultation Read code within a 12-month period. Yearly estimates were taken from 2000-2015. 95% confidence intervals were calculated using a Poisson regression online calculator, as the count of X-ray request events in the population represented by this data is assumed to follow a Poisson distribution. This assumes that an average number of events occurs within a period, but that each event occurs independently of one another in time and space. In subsequent analysis the numerator population was stratified by gender, GP practice, age at index OA consultation and IMD quintiles. Trend lines were estimated using Microsoft word for each GP practice (Microsoft 365, 2006). Age was stratified into 10-year intervals (45-54,55-64,65-74,75+). Bedson, Jordan & Croft (2005) found that the decision to X-ray is related to both age and gender. If there are changes in the age and sex characteristics of the OA population in this study, this could potentially explain changes in the rate of X-ray requests over time. To control for possible changes in the age and sex distribution of OA consulter over time, I standardised the age and sex characteristics of the OA population using the 2012 CiPCA population for reference.

Objective 2- Explore whether any changes over time in the above proportion coincided with the publication of relevant NICE and RCR guidelines.

Quarterly estimates were calculated for the proportion of patients who received an X-ray request for OA. Joinpoint regression software was used to identify the line of best fit using the minimum number of joinpoints at a significance level of 0.05. The model specification allowed a minimum of 0 joinpoints to a maximum of 9. The Poisson variance error model was chosen as I was analysing count data (National Cancer Institute, 2016).

The location of any joinpoints were then compared with the publication dates of national guidelines (Table 4-3). If no joinpoints are found, there are no significant changes in the trend in X-ray request rates. If a joinpoint aligns with the publication of a guideline, this may indicate that guidelines have had some impact on X-ray request rates. If a joinpoint does not align with a

guideline publication, this could indicate another factor not accounted for is impacting X-ray request rates.

Table 4-3: The guideline recommendations and publication dates for osteoarthritis from 2000-2015

Publication date	Publisher	Guideline	Guideline recommendation
30th June 2003	RCR	Making the best use of a department of clinical radiology: guidelines for doctors.	• X-ray of pelvis is indicated in specific circumstances of hip pain* • X-ray of knee is indicated in specific circumstances of knee pain* • X-ray of the hands and feet are indicated • X-rays may be necessary for specialist assessment • X-rays are necessary for knee replacement surgery
1st September 2007	RCR	Making the Best Use of Clinical Radiology Services	• X-ray of pelvis is indicated for hip pain* • X-ray of knee indicated in specific circumstances of knee pain • X-ray of the hands and feet are indicated • X-rays may be necessary for specialist assessment • X-rays are necessary for knee replacement surgery
27th February 2008	NICE	Osteoarthritis: the care and management of osteoarthritis in adults	• In patients with typical symptoms of OA, further investigations are not necessary
23rd February 2012	RCR	iRefer: making the best use of clinical radiology.	• X-ray of pelvis is indicated for hip pain • X-ray of knee is indicated in specific circumstances of knee pain • X-ray of the hands and feet are indicated • X-rays may be necessary for specialist assessment • X-rays are necessary for knee replacement surgery
12th February 2014	NICE	Osteoarthritis: care and management	• In patients with typical symptoms of OA, further investigations are not necessary

NICE: National Institute for Health and Clinical Excellence, RCR: Royal college of Radiology.
Guideline recommendations adapted from NICE (2014), (2008); Royal College of Radiologists (2017), (2003), (2007)

* Change in guideline recommendation from previous edition

Objective 3: Estimate the proportion of patients who are referred to secondary care following an X-ray request for OA, and changes in this proportion during the period 2000-2015

Objective three assessed the proportion of patients who were referred to secondary care following an X-ray for OA. The denominator was the annual number of patients with a recorded X-ray Read code within 30 days either side of a recorded clinical OA Read code. The numerator was the annual number of patients with a recorded secondary care referral Read code, within 30 days either side of a clinical OA consultation that was associated with an X-ray request (Table 4-1). Only one clinical OA consultation associated with an X-ray request was counted per patient, per year, and only one specialist referral was counted per patient per year. A sensitivity analysis then explored how the trend in referrals following an X-ray changed with increasing time periods between the referral Read code and the clinical OA consultation Read code. Three additional time periods were included in this sensitivity analysis (Figure 4-1).

A subsequent analysis stratified the annual number of patients with a recorded secondary care referral Read code by the specialities outlined in Table 4-1. Only one referral was counted for each patient per year. The same denominator was used as outlined above.

Objective 4: Analyse the direction and magnitude of association between patient characteristics, the practice a patient belongs to, and the likelihood of an X-ray request for OA.

I used a three-step binary logistic regression model to estimate the direction and magnitude of effect between a patient characteristic and the likelihood of requesting an X-ray for OA. The first step calculated a crude odds ratio (for each of: age, sex, IMD quintile, anxiety, depression, ethnicity, and the practice a patient was registered with) for X-ray requests for OA. The second step adjusted for the above patient characteristics through a multivariable model. The third step included the general practice a patient was registered to as an additional co-variate in the multivariable model. Odds ratios (OR) and 95% confidence intervals were estimated for each relevant co-variate, at each step.

Conducting multiple statistical analyses on a single sample of data increases the risk of a type 1 error, i.e. false positive associations between an outcome and a predictor (Rothman, 1990) Researchers can reduce the risk of type 1 errors through decreasing the p-value, however this adjustment increases the probability of a type 2 error, which is when an important association in the real world is found to be insignificant in the statistical analysis (Rothman, 1990). As the aim of this study is exploratory, I have not undertaken an adjustment for multiple comparison as this would reduce the ability of the current study to identify potentially relevant determinants of an X-ray request, which could be investigated further.

4.5 Results

4.5.1 Cohort characteristics

Of the nine GP practices included in this study from 2000-2015, a total of 23,784 patients had at least one OA consultation. 13,657 (58.3%) were females and 18,984 (79.8%) were white or white British. The median age at first recorded OA consultation between 2000-2015 was 62 years (IQR: 54.0,73.0). The population was disproportionately deprived with only 3,581 patients (15.1%) living in neighbourhoods categorised within the 40% least deprived areas in England (i.e. IMD quintile 4 or 5).

Table 4-4: Baseline characteristics of the OA population	
Baseline OA population characteristics	**Frequency (%)**
Female gender	13,857 (58.3)
Age	
45-54	6,586 (27.7)
55-64	6,550 (27.5)
65-74	5,357 (22.5)
75+	5,291 (22.5)
Ethnicity	
Not coded	4,528 (19.0)
White or white British	18,984 (79.8)
Asian or Asian British	170 (0.7)
Black or black British	39 (0.2)
Other ethnic group	25 (0.1)
Mixed ethnicity	38 (0.2)
GP practice	
1	3,704 (15.6)
2	2,323 (9.8)
3	2,252 (9.5)
4	3,242 (13.6)
5	3,230 (13.6)
6	2,728 (11.5)
7	3,247 (13.7)
8	936 (3.9)
9	2,122 (8.9)
IMD quintile	
1 (most deprived)	2,341 (9.8)
2	7,921 (33.3)
3	9,941 (41.8)
4	3,550 (14.9)
5 (least deprived)	31 (0.1)
Depression Read code 12 months either side of the index OA consultation	3,755 (15.8)
Anxiety Read code 12 months either side of the index OA consultation	2,158 (9.1)
Joint pain Read code	59,388 (56.3)

4.5.2 Preliminary analysis and data quality

Yearly X-ray request rates from 2000-2015 are illustrated in Figure 4-2. X-ray Read codes related to requests from the "Operations, Procedures, and Investigations" domain, rather than Read codes related to X-ray results from the "Clinical Findings" domain, made up the largest proportion of X-ray events counted (66%). The rate of observed X-ray requests rose markedly in the period 2013-2015. In 2015, I identified that 31.8% of all OA consultations resulted in an X-ray request across the nine GP practices. Practices 3 and 8 had consistently and implausibly low levels of X-ray coding until 2013 (Figure 4-3). This low level of coding is likely due to these practices operating a paper-based system, where X-ray requests and results were communicated without entering Read codes on the patients' EHRs. This rise in X-ray coding from 2013 onwards, particularly dramatic in practices 3 and 8, corresponded with the phased introduction of a clinical information system in the North Staffordshire area (Bostock, 2014). This software package facilitated the electronic requesting of X-rays and automatic recording of X-ray results on primary care EHRs. This improved the accuracy of estimates from 2013-2015. However, the aim of this chapter was to explore the association between publication of national OA guidelines and the use of X-rays in primary care. The substantial changes in coding practices could distort trend rates and result in the identification of a joinpoint associated with changing coding practices rather than X-ray request behaviour. To reduce the impact that changing coding practices could have on the study conclusions, I restricted the analysis to 2000-2012. As practices 3 and 8 had a dramatic rise in their X-ray request rate from 2013 to a rate similar to other practices in this population, this is consistent with the belief that practice 3 and 8's low X-ray request rate from 2000-2012 was likely due to poor electronic coding rather than low X-ray use. Practices 3 and 8 were excluded in the assessment of the trend in X-ray requests over time to reduce the risk of bias in the trend analysis (as their X-ray request rates were low but lacked variation, their inclusion would have biased the overall trend toward no change).

Figure 4-2: Trend in X-ray request rates across all nine practice from 2000-2015

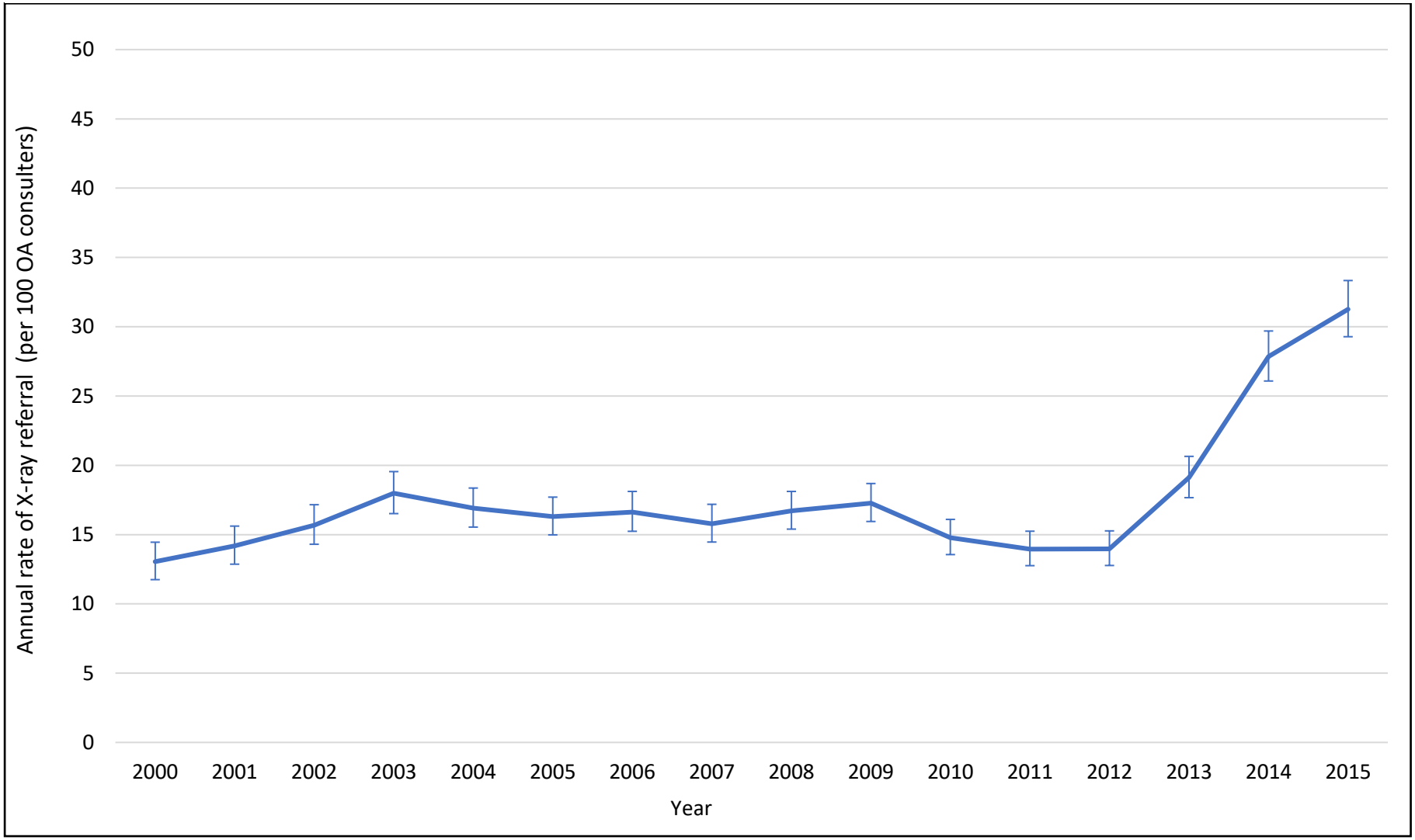
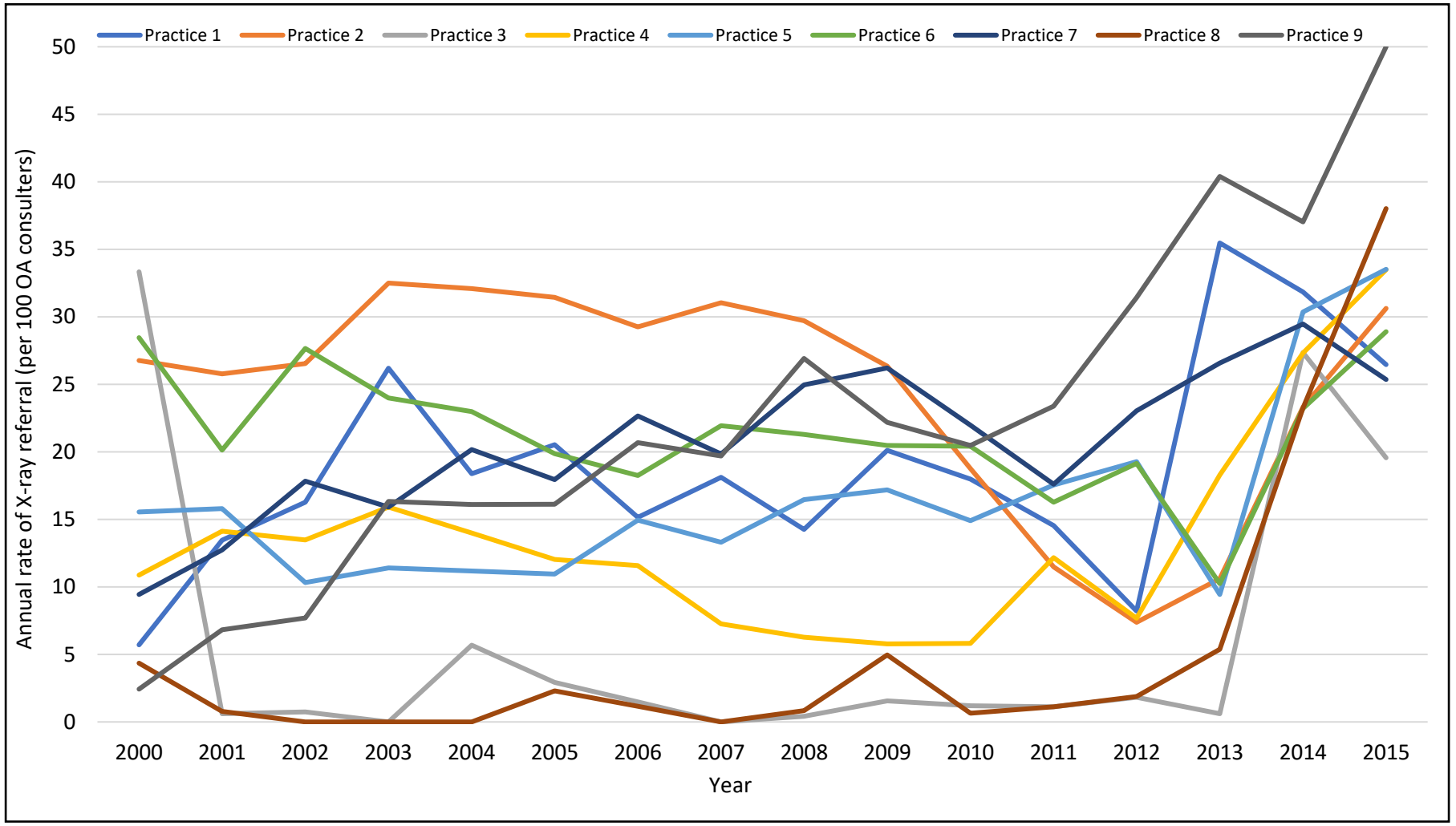


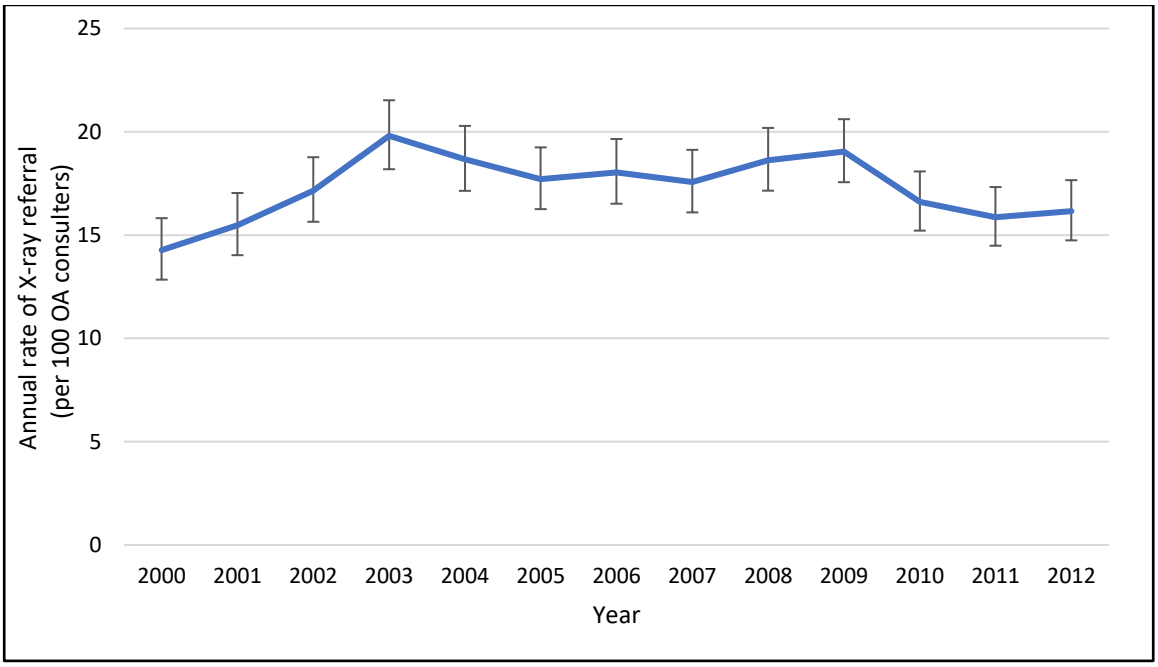
Figure 4-3 Trend in X-ray request rates from 2000-2015 stratified by nine GP practices



4.5.3 Rate of X-ray requests from 2000 to 2012.

The rate of X-rays requested remained generally constant over the study period (Figure 4-4), averaging 17.3 X-rays per 100 patients consulting for OA per year (range:14.3 (2000), to 19.8 (2003)). From 2000-2003 there was a slight increase in X-ray request rates, and from 2009-2012 a slight decrease in X-ray request rates. The largest percentage increase was 15.5% and occurred between 2002 and 2003. 2003 had the highest rate of X-ray requests, with 19.8 X-rays per 100 patients consulting for OA. The largest annual percentage decrease was 12.8%, which occurred from 2009 to 2010.

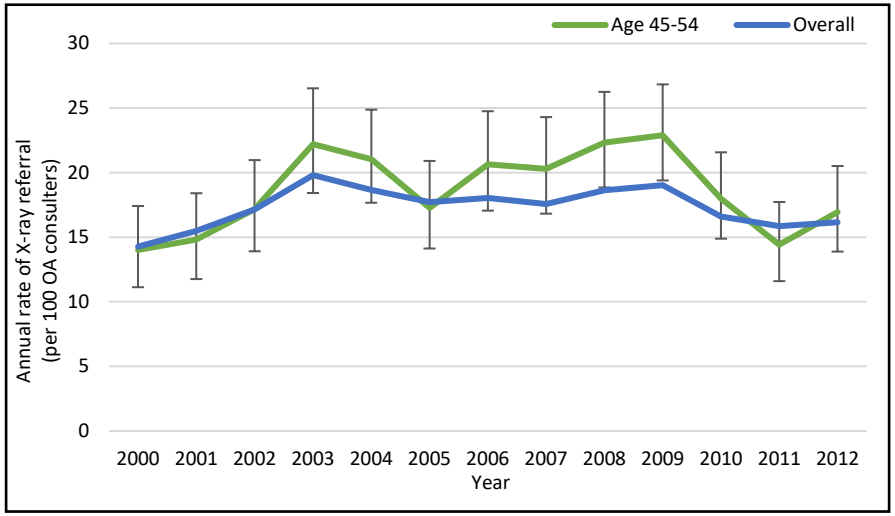
Figure 4-4: Trend in X-ray rates from 2000-2012 excluding practices 3 and 8

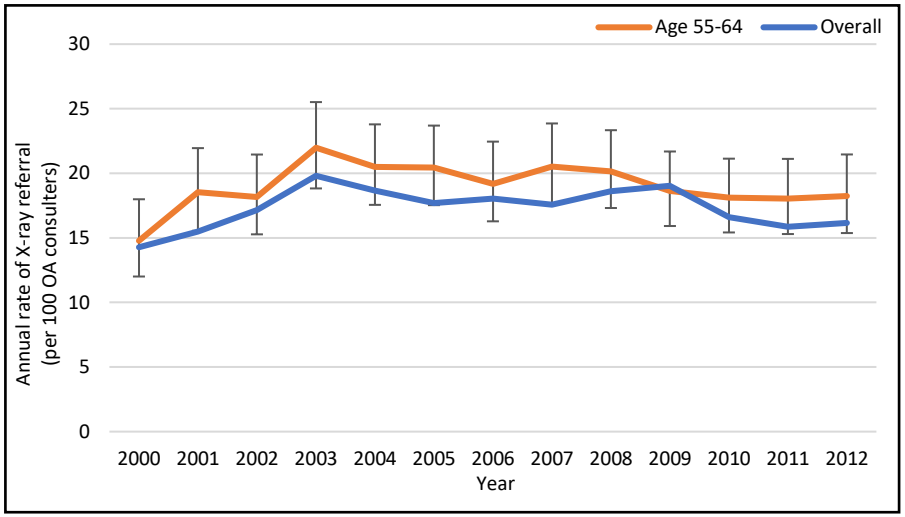


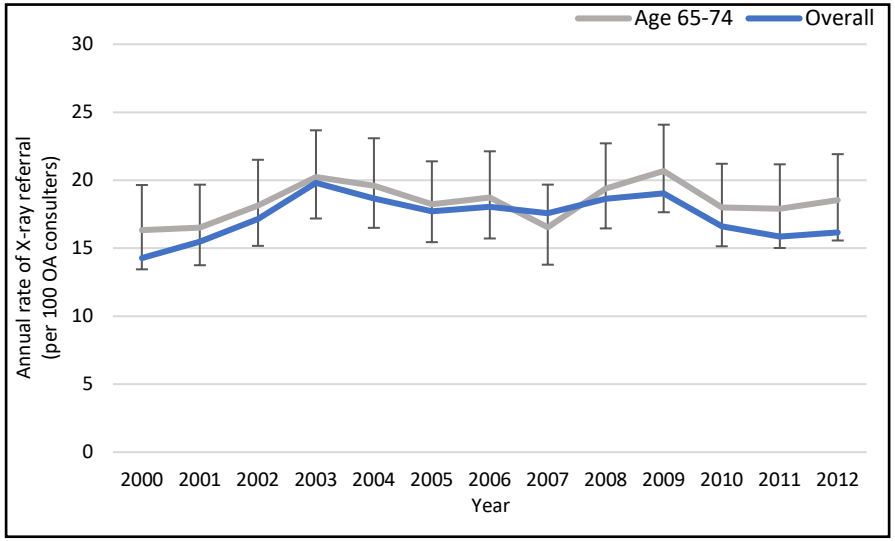
4.5.4 Age

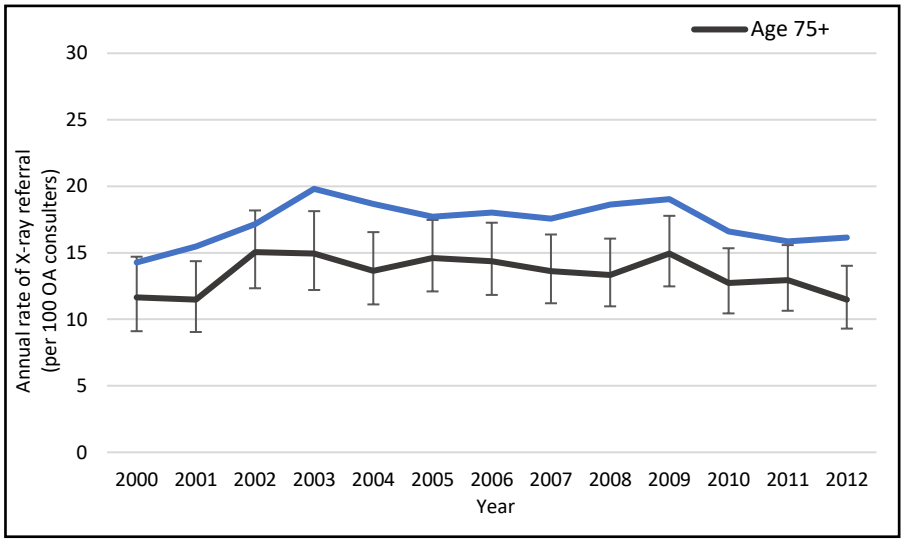
The trend in X-ray request rates stratified by age is presented in Figure 4-5. Those aged ≥75 years of age had a mean annual request rate of 13.4 X-rays per 100 patients consulting for OA (range: 11.48 (2000 and 2012), to 15.05 (2003)). Patients aged ≥75 years had a consistently lower rate of X-ray requests when compared to all other age groups. Those in the 55-64 age group had the highest rate of X-ray requests over the 13-year period, with a mean annual request rate of 19.2 X-rays per 100 patients consulting for OA (range: 14.8 (2000), to 22.0 (2003)).

Figure 4-5 Trend in X-ray request rates from 2000-2012: Stratified by age





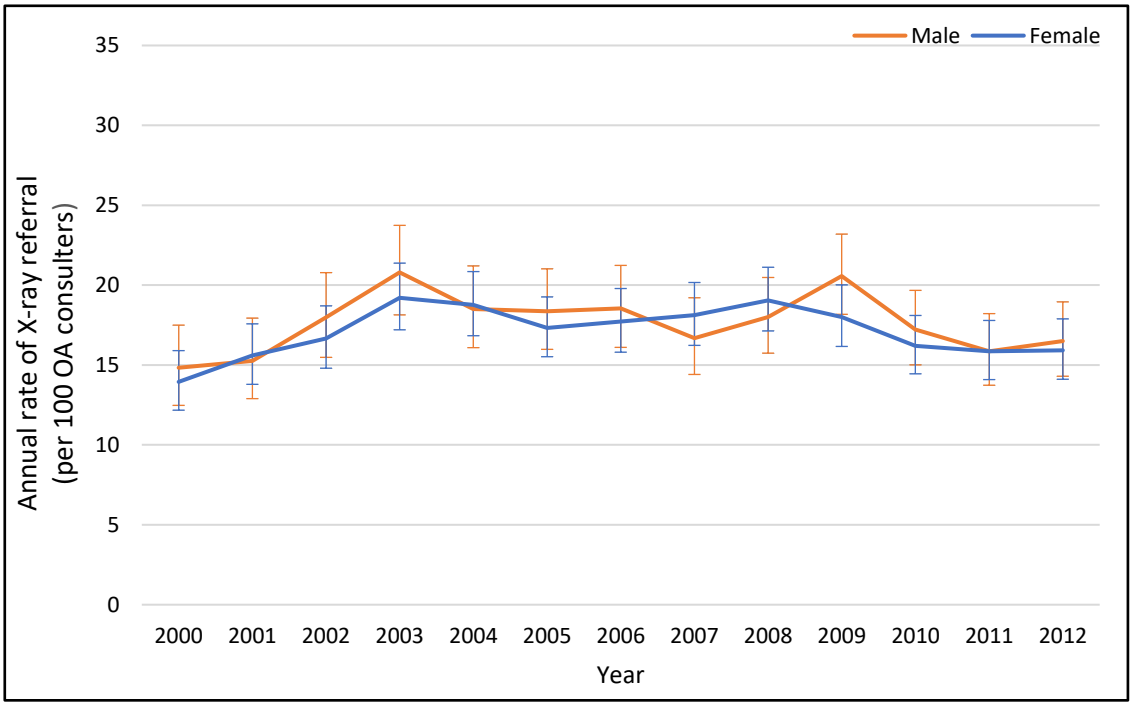




4.5.5 Sex

The mean annual X-ray request rate in males was 17.6 X-rays per 100 patients consulting for OA (range: 14.8 (2000), to 20.8 (2003). The mean annual X-ray request rate in females was 17.1 X-rays per 100 patients consulting for OA (range: 14.0 (2000), to 19.2 (2003)).

Figure 4-6: Trend in X-ray rates from 2000-2012: stratified by sex



4.5.6 Age and sex standardisation

Age and sex-standardised estimates were produced to account for the potentially changing population characteristics from 2000-2012 (Table 4-4). The similar estimates between the unadjusted and adjusted rate of X-ray requests indicates that the age and sex characteristics of the OA population remained approximately constant from 2000-2012.

Table 4-5: The crude and age and sex standardised estimates for the rate of X-ray requests per 100 patients consulting for OA

Year	Crude rate (95% CI)	Age- and sex-standardised rate (95% CI)
2000	14.3 (12.8, 15.8)	14.0 (12.7, 15.4)
2001	15.5 (14.0, 17.0)	15.3 (14.0, 16.8)
2002	17.2 (15.7, 18.8)	16.9 (15.5, 18.5)
2003	19.8 (18.2, 21.5)	19.6(18.1, 21.3)
2004	18.7 (17.1, 20.3)	18.4 (16.8, 19.5)
2005	17.7 (16.3, 19.3)	17.6 (16.1, 19.2)
2006	18.0 (16.5, 19.7)	18.0 (16.5, 19.6)
2007	17.6 (16.1, 19.1)	17.5 (16.0, 19.1)
2008	18.6 (17.2, 20.2)	18.5 (17.0, 20.1)
2009	19.0 (17.6, 20.6)	18.9 (17.4, 20.6)
2010	16.6 (15.2, 18.1)	16.5 (15.1, 18.1)
2011	15.9 (14.5, 17.3)	15.8 (14.4, 17.3)
2012	16.2 (14.8, 17.7)	16.2 (14.8, 17.7)

Reference population: 2012

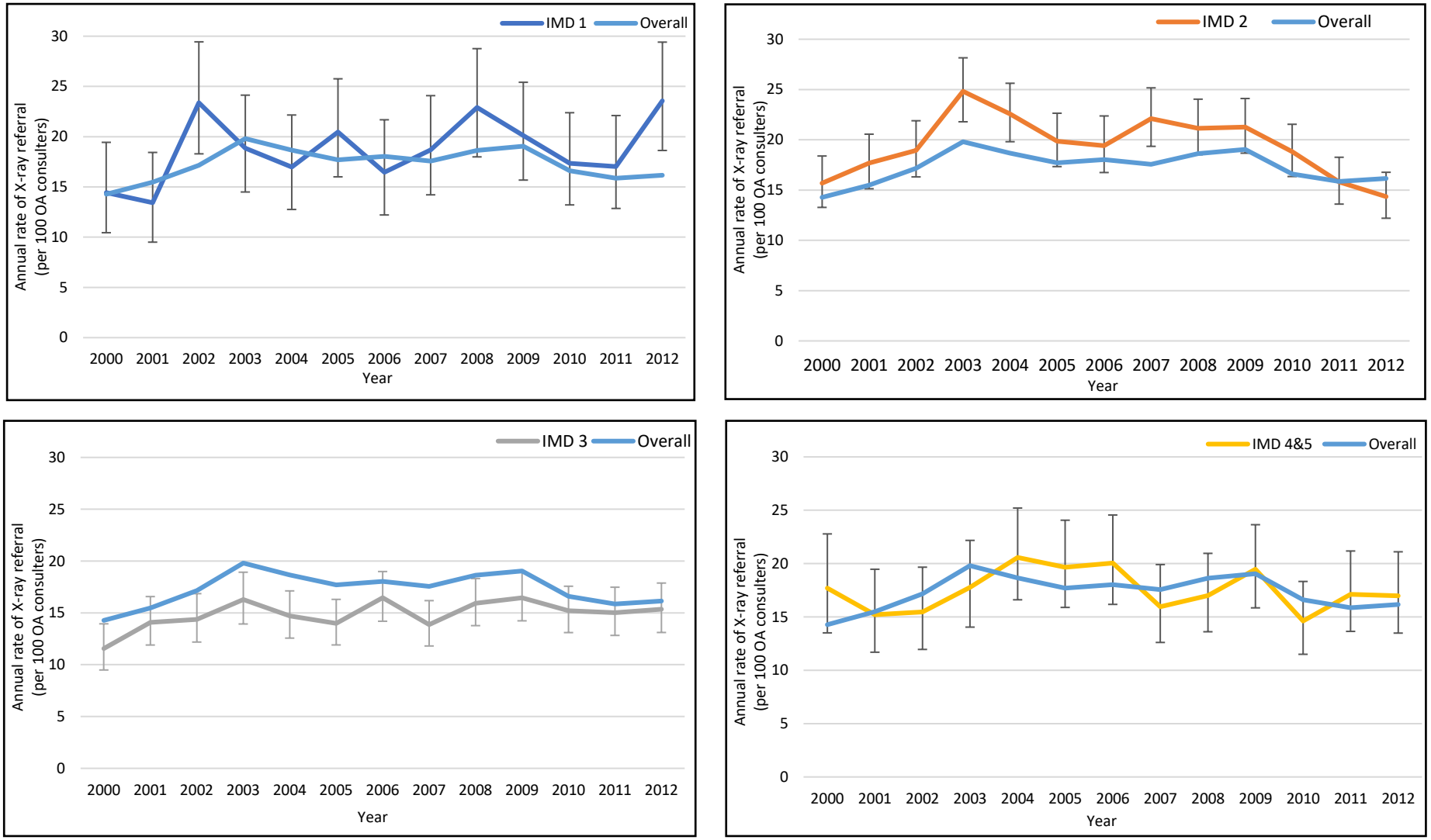
4.5.7 Relative deprivation

Due to local social deprivation, few patients were classified in IMD quintile 5. Due to the small numbers, IMD quintile 4 and 5 were merged. IMD 3 on average had the lowest rate of X-ray requests (Figure 4-8). The highest average rate of X-rays requested over the 13-year period was found in IMD 2.

Table 4-6: Average incidence rate of X-rays from 2000-2012 split by IMD group

IMD group	**Average number of X-rays per 100 patients consulting for OA (Range)**
IMD 1 (most deprived)	18.7 (14.4 (2000), to 23.6 (2012))
IMD 2	19.4 (15.7 (2000), to 22.3 (2003))
IMD 3	14.9 (11.6 (2000), to 16.5 (2006))
IMD 4&5 (least deprived)	17.5 (14.6 (2010), to 20.6 (2004))

Figure 4-7: Trend in X-ray request rates from 2000-2012: stratified by relative level of deprivation



4.5.8 GP practice

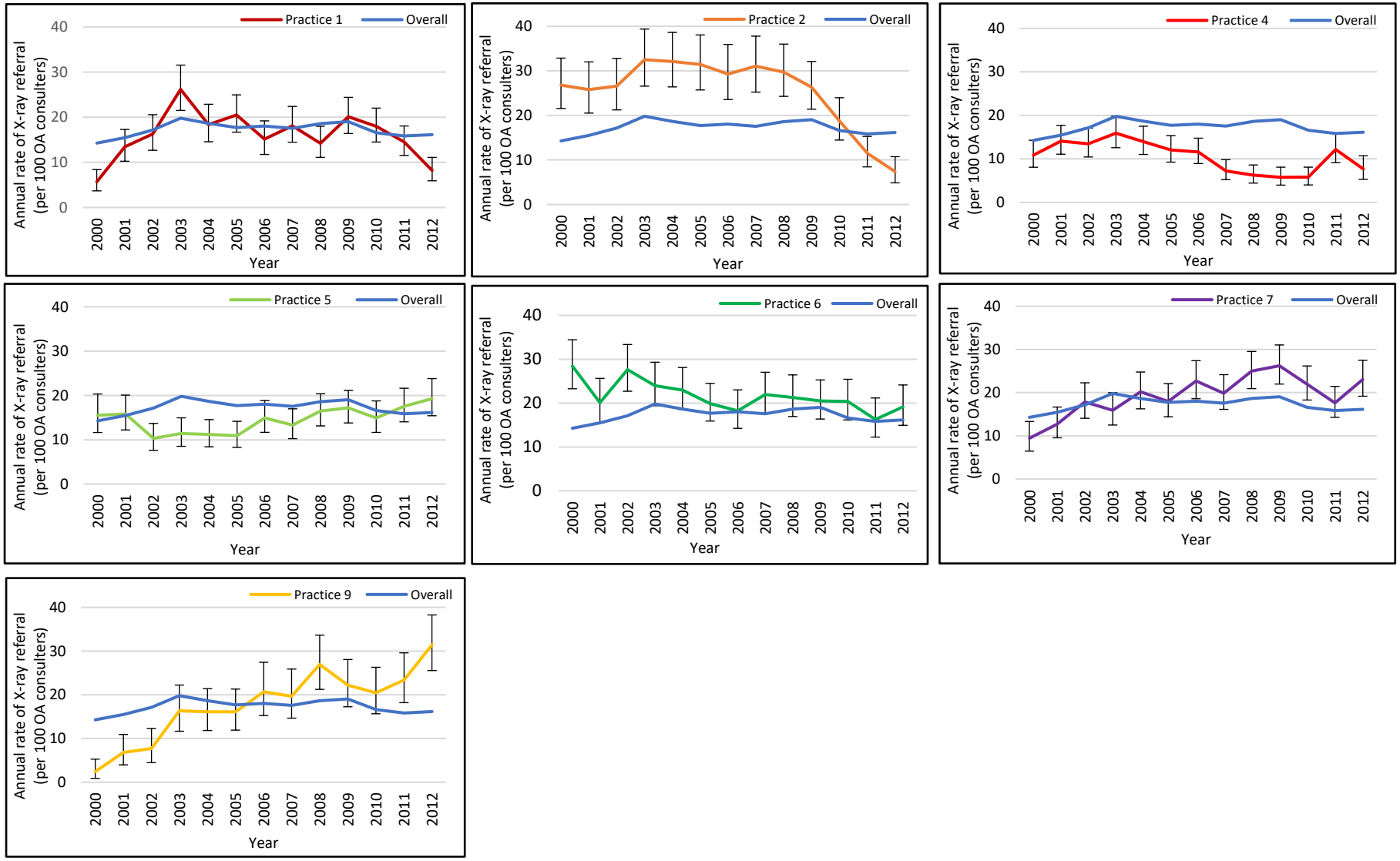
There was evidence of variation in the crude rates of X-rays requested between practices (Figure 4-8). The following estimates are the practice mean annual X-ray requests per 100 OA consulters from 2000-2012.

By inspection, practice 1 showed marked variation in X-ray request rates from 2000-2012. However, when this variation is averaged over the 13-year period, the secular trend in X-ray requests appears constant, with a mean annual request rate of 16.1 X-rays per 100 patients consulting for OA (range: 5.7 (2000), to 26.2 (2003).

Practices 2, 4 and 6 showed an overall decreasing trend in X-ray requests from 2000-2012. Of the three practices that showed a decreasing trend, practice two had the highest mean annual request rate at 25.3 X-rays requested per 100 patients consulting for OA (range: 7.4 (2012), to 32.5 (2003)). At practice six, the mean annual request rate was 21.6 X-rays requested per 100 patients consulting for OA (range: 16.3 (2011), to 28.5 (2000)). Of the three practices that showed a decreasing trend, practice 4 had the lowest mean annual request rate, at 10.5 X-rays requested per 100 patients consulting for OA (range: 5.8 (2009 and 2010), to 15.9 (2003)).

Practices 5, 7 and 9 showed an overall increasing trend in X-ray request rates. The mean annual X-ray request rates amongst the three practices showing an increasing trend appeared less heterogenous than the three practices showing a decreasing trend. At practice 7, the mean annual request rate was 19.3 X-rays requested per 100 patients consulting for OA (range: 9.4 (2000), to 26.2 (2009). At practice 9 the mean annual request rate was 17.7 X-rays requested per 100 patients consulting for OA (range: 2.4 (2000), to 31.4 (2012)) and at practice 5 the mean annual X-ray request rate was 14.5 X-rays requested per 100 patients consulting for OA (range: 10.3 (2002), to 19.3 (2012)).

Figure 4-8: Trend in X-ray request rates: stratified by GP practice



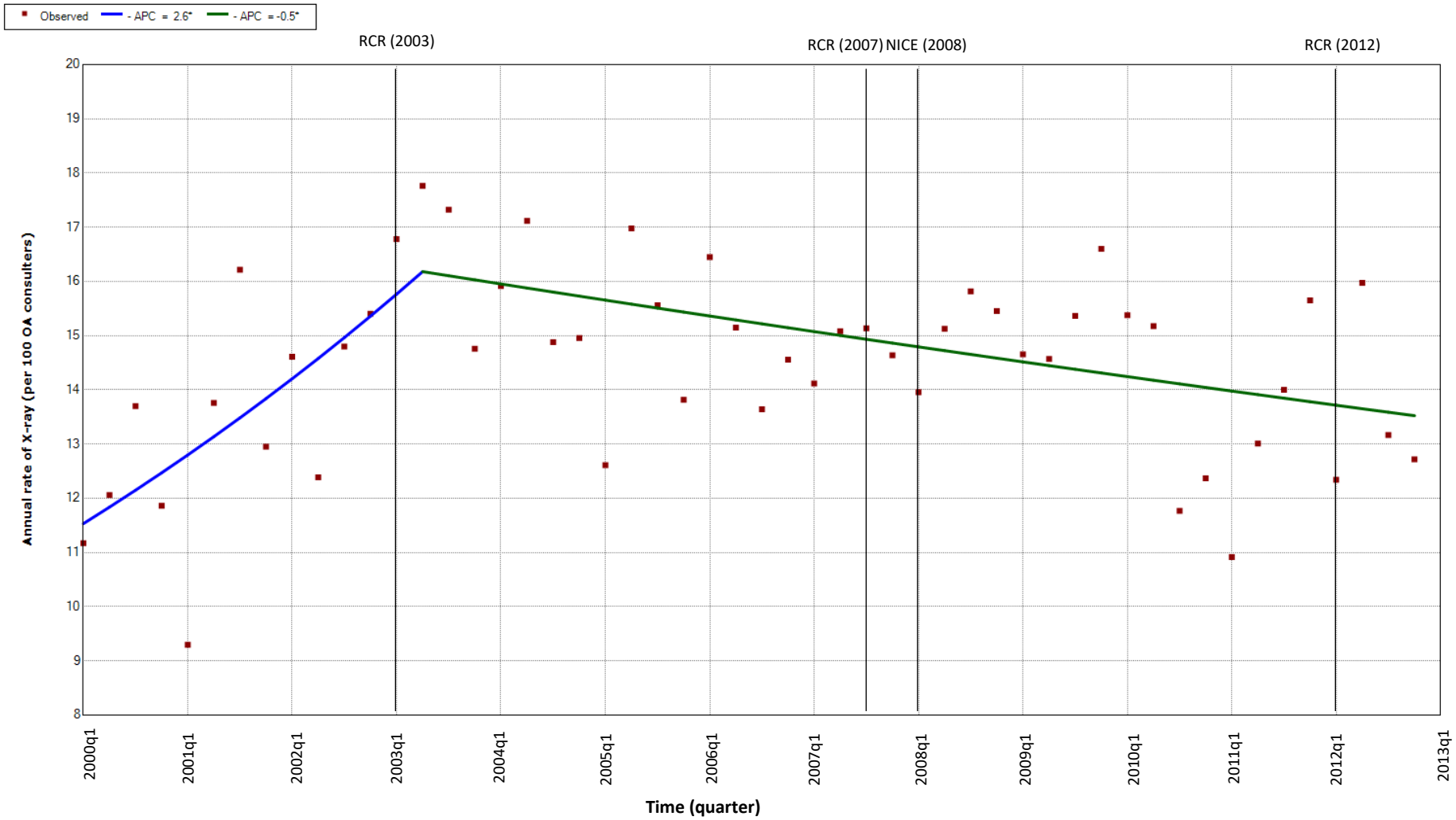
4.5.9 Relationship between guideline publication and trend in X-ray request rate

Two segments were identified through the joinpoint analysis (Figure 4-9). The first segment was from 2000q1 to 2003q2. The percentage change per quarter for this segment was 2.6 percent (95% CI:1.0, 4.3).

One joinpoint was identified at 2003Q2 (95% CI: 2002Q2,2004Q2). This joinpoint coincides with the publication of the Royal College of Radiologists guideline “Making the best use of a department of clinical radiology: guidelines for doctors”, which was published in June 2003.

The second segment of the analysis showed a decreasing trend from 2003Q2 to 2012Q4. The percentage change per quarter for this segment was -0.5% (95% CI: -0.8, -0.2).

Figure 4-9: Graph illustrating the trend in X-ray requests from 2000-2012, with superimposed national OA guidelines publication dates



4.5.10 Proportion of patients referred to secondary care referral following an X-ray request for osteoarthritis

Across 2000-2012, an annual average of 18.7% of patients consulting for OA with an associated X-ray, received a specialist referral (range: 15.2 (2007), to 21.7 (2003)).

A sensitivity analysis explored how the rate of referral changed with increasing time periods between the referral Read code and the clinical OA consultation Read code. For each step in the sensitivity analysis, I increased the inclusion period by 30 days (Figure 4-1). When the inclusion period increased, the proportion of patients who went on to receive a secondary care referral following an X-ray request for OA increased. The overall trend however, remained robust to increasing time window between the referral Read code and the clinical OA consultation Read code (Figure 4-10). The focus of the specialist referrals was 30 days either side of the index OA consultation which resulted in an X-ray (Figure 4-11).

Over the 13-year period, recorded referrals to occupational therapists, orthotists, chiropodists, pain clinics, dieticians, weight management programmes and surgical fitters were very low (Figure 4-11). The mean coded recorded referral rate to these specialists from 2000-2012 ranged from 0.7% (chiropodist) to 0.0% (weight management). Therefore, these were collectively analysed as “other”.

The rate of rheumatology referrals was low. From 2000-2012, the mean annual recorded referral rate was 1.8% of patients consulting for OA with an associated X-ray request (range: 1.6% (2011), to 2.9% (2009)). Similarly, a mean annual rate of 1.3% of patients consulting for OA with an associated X-ray request were recorded as referred to the specialities collectively labelled “other” from 2000-2012 (range: 0.6% (2006), to 2.4 (2000)).

The rate of both orthopaedic and physiotherapy recorded referrals was higher than that of rheumatology and “other” referrals. From 2000-2012, a mean annual rate of 9.0% of patients consulting for OA with an associated X-ray request were referred to an orthopaedic surgeon within 30 days (range:3.3% (2000), 11.6% (2008)). This showed an overall increase in trend from

2000-2012. However, the rate of physiotherapy referrals showed a decreasing trend from 2000-2012, with a mean annual rate of 6.7% of patients consulting for OA with an associated X-ray request received a physiotherapy referral (range:4.6% (2008), 9.5% (2000)).

Figure 4-10: Rate of secondary care referrals within 30, 60, 90, and 120 days of a clinical OA consultation associated with an X-ray

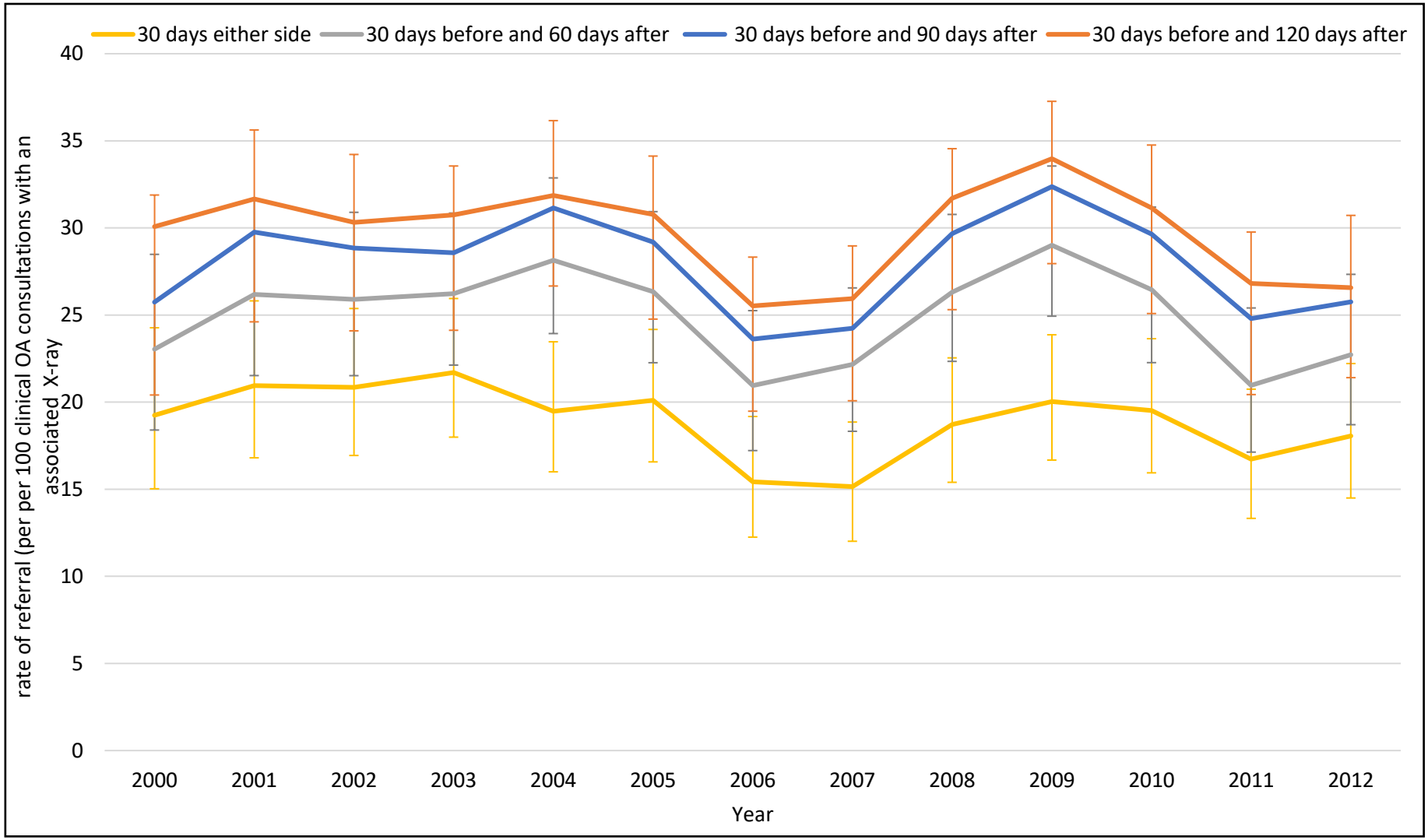
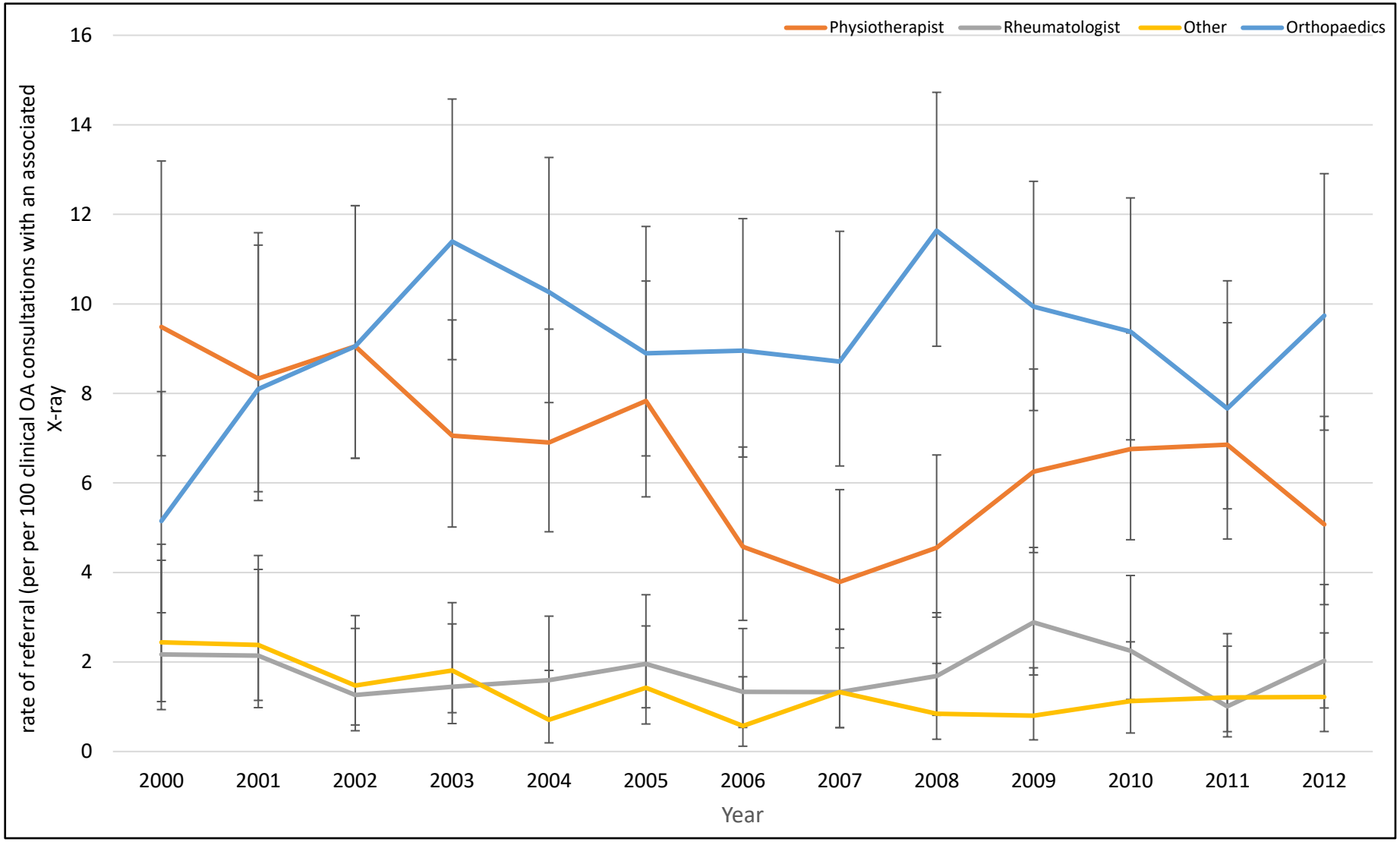


Figure 4-11: Rate of secondary care referrals within 30 days either side of a clinical OA consultation associated with an X-ray: Stratified by speciality



4.5.11 Factors associated with X-ray requests.

A three-step model was constructed to estimate the direction and magnitude of effect of a range of patient characteristics, and the practice a patient is registered, on whether an X-ray was requested for OA (Table 4-6).

Females were at a slight increased likelihood of being requested an X-ray for OA when compared to men. However, the magnitude of effect for this association was weak. The statistical significance diminished when patient factors and practice were adjusted for.

An association was found between increasing age, but only up to the age of 74 and the likelihood of an X-ray request for OA. Patients aged 55-64 were significantly more likely to have an X-ray requested when compared to patients aged 45-54 years old, whilst patients aged 65-74 had a similar likelihood of an X-ray being requested when compared to patients aged 45-54. The strongest association was found in patients aged ≥75 years. Patients aged ≥75 years of age were the only age group which were less likely to receive an X-ray request for OA, when compared to patients 45-54 years old.

An inverse association was found between increasing relative deprivation and the likelihood of an X-ray request for OA, as when adjusted for both patient factors and the practice a patient was registered, as the relative deprivation level decreased, the likelihood of an X-ray request for OA increased. The magnitude of association was strongest for the least deprived patients (IMD 4&5), which was statistically significant.

Frequency of consultation between 2000-2015 showed the strongest positive association with a likelihood of receiving an X-ray for OA. With patients consulting 1-3 times as the reference category, as the frequency of consultation increased between each category, the likelihood of an X-ray being requested also increased. The magnitude of association was stronger when other patient characteristics, and the practice a patient was registered with, were adjusted for.

Apart from practice 7, the practice a patient was registered with was statistically significantly associated with the likelihood of an X-ray being requested when compared to practice 1. Practice 4, 5 and 7 showed a decreased likelihood of an X-ray request for OA when compared to practice 1. The magnitude of association also varied, with patients belonging to practice 4 the least likely to request an X-ray for OA when compared to practice 1. However, being registered to practices 2, 6 and 9 was associated with an increased likelihood of requesting an X-ray for OA. The importance of which practice a patient is registered is further exemplified by the estimated likelihood ratio test statistics. The Nagelkerke R^2 statistic for the model that adjusts for only patient characteristics is 0.23. However, when I additionally adjusted for the practice a patient is registered with, this increased to 0.25. The model factoring in the measured patient characteristics and the practice identifier explained 25% of the variance in recorded X-ray requests for OA.

Table 4-7: The impact of patient and the practice a patient is registered to on the likelihood of receiving an X-ray request for OA

	Unadjusted		**Adjusted for patient factor**		**Adjusted for patient factors and practice**	
	Odds ratio	95% CI	Odds ratios	95% CI	Odds ratios	95% CI
Sex male (reference)	1.00		1.00		1.00	
Sex female	1.08	(1.02, 1.14)	1.06	(0.99, 1.13)	1.06	(0.99, 1.13)
Age 45-54 (reference)	1.00		1.00		1.00	
Age 55-64	1.20	(1.11, 1.29)	1.15	(1.06, 1.25)	1.15	(1.06, 1.25)
Age 65-74	1.12	(1.03, 1.21)	1.03	(0.95, 1.13)	1.05	(0.96, 1.14)
Age 75+	0.58	(0.53, 0.63)	0.61	(0.55, 0.67)	0.62	(0.56, 0.68)
Ethnicity White (reference)	1.00		1.00		1.00	
Ethnicity Unknown	0.57	(0.52, 0.62)	0.86	(0.78, 0.95)	0.83	(0.75, 0.92)
Ethnicity Non-white	0.91	(0.70, 1.18)	0.86	(0.65, 1.15)	0.76	(0.58, 1.04)
IMD 1 (reference)	1.00		1.00		1.00	
IMD 2	1.02	(0.93, 1.12)	1.02	(0.92, 1.14)	1.05	(0.93, 1.19)
IMD 3	0.83	(0.75, 0.91)	0.72	(0.65, 0.80)	1.16	(1.00, 1.34)
IMD 4&5	1.05	(0.94, 1.17)	0.92	(0.81, 1.04)	1.24	(1.05, 1.46)
Depression within 12 months either side of OA consultation	1.39	(1.28, 1.49)	0.93	(0.85, 1.02)	0.90	(0.82, 0.99)

Anxiety within 12 months either side of OA consultation	1.44	(1.31, 1.58)	0.99	(0.88, 1.11)	1.00	(0.89, 1.12)
1-3 OA consultations from 2000-2015 (reference)	1.00		1.00		1.00	
4-6 OA consultations from 2000-2015	3.42	(3.18, 3.70)	3.66	(3.38, 3.96)	3.77	(3.48, 4.09)
7-9 OA consultations from 2000-2015	5.50	(4.95, 6.11)	6.11	(5.47, 6.82)	6.39	(5.72, 7.14)
10+ OA consultations from 2000-2015	9.63	(8.73, 10.63)	11.07	(9.95, 12.32)	11.69	(10.48, 13.04)
Calendar year 2003 (reference)	1.0		1.0		1.0	
Calendar year 2000	0.92	(0.81, 1.05)	0.70	(0.61, 0.82)	0.70	(0.60, 0.81)
Calendar year 2001	0.90	(0.79, 1.04)	0.80	(0.68, 0.94)	0.82	(0.70, 0.96)
Calendar Year 2002	0.87	(0.75, 1.00)	0.82	(0.70, 0.97)	0.83	(0.71, 0.98)
Calendar year 2004	0.83	(0.71, 0.96)	0.83	(0.70, 0.98)	0.83	(0.70, 0.98)
Calendar year 2005	0.89	(0.77, 1.04)	0.97	(0.82, 1.15)	0.98	(0.82, 1.16)
Calendar year 2006	0.87	(0.75, 1.02)	0.99	(0.83, 1.18)	1.00	(0.84, 1.19)
Calendar year 2007	0.75	(0.64, 0.88)	0.86	(0.72, 1.02)	0.86	(0.72, 1.03)
Calendar year 2008	0.68	(0.58, 0.80)	0.85	(0.71, 1.01)	0.84	(0.70, 1.01)
Calendar year 2009	0.71	(0.61, 0.84)	0.91	(0.76, 1.08)	0.91	(0.76, 1.08)

Calendar year 2010	0.59	(0.50, 0.70)	0.79	(0.66, 0.96)	0.80	(0.66, 0.96)
Calendar year 2011	0.55	(0.46, 0.65)	0.77	(0.64, 0.94)	0.76	(0.63, 0.92)
Calendar year 2012	0.55	(0.46, 0.65)	0.84	(0.69, 1.02)	0.83	(0.69, 1.01)
Calendar year 2013	0.63	(0.53, 0.75)	0.98	(0.81, 1.19)	0.95	(0.78, 1.15)
Calendar year 2014	0.91	(0.77, 1.09)	1.64	(1.36. 1.99)	1.63	(1.34, 1.97)
Calendar year 2015	1.07	(0.89, 1.28)	2.03	(1.67, 2.47)	2.06	(1.69, 2.50)
Practice 1 (reference)	1.00				1.00	
Practice 2	1.68	(1.51, 1.87)			1.58	(1.40, 1.78)
Practice 4	0.83	(0.75, 0.92)			0.52	(0.46, 0.60)
Practice 5	0.87	(0.79, 0.97)			0.65	(0.58, 0.74)
Practice 6	1.36	(1.23, 1.51)			1.17	(1.03, 1.33)
Practice 7	1.37	(1.24, 1.51)			0.98	(0.86, 1.12)
Practice 9	1.32	(1.18, 1.48)			1.35	(1.18, 1.54)

4.6 Discussion

4.6.1 Comparison with existing literature

Rate of X-ray requests in patients consulting for OA

There is little evidence that additional radiographic features improve diagnostic certainty in patients with typical clinical features (Skou, Thomsen & Simonsen, 2014). However, the role of radiography in OA is likely to change. The current shift from face to face consultations to remote consultations as a result of Covid-19 reduces the opportunity for practitioners to examine the joint (Greenhalgh, Koh & Car, 2020). In these remote consultations, it seems probable that additional imaging may be used by clinicians in an attempt to improve diagnostic certainty.

It is important to understand the context in which the X-rays were taken, to speculate if the rate of X-ray requests is acceptable. The findings of this research project are drawn from the context of face to face consultations. This may reduce the relevance of these findings in the context of remote consultations.

In the context of face to face consultations, evidence did not suggest any additional benefit of radiography in diagnosing a patient with typical OA clinical features (Skou, Thomsen & Simonsen, 2014). Furthermore, the routine use of X-rays in OA management was also associated with negative consequences (Morgan *et al.*, 1997). This is because radiographic findings do not correlate well with the patient experience of the illness and do not helpfully predict outcomes from core interventions (Bedson & Croft, 2008). If advanced disease is identified radiographically before core interventions have been tried, this may result in unnecessary referrals (van den Bogaart *et al.*, 2019). Alternatively, a patient with symptoms unresponsive to core management strategies may not be referred if they have mild radiographic features. Little evidence exists as to the rate of X-ray requests for OA in the UK.

Yu et al. (2017) estimated the rate of X-ray requests for incident cases of OA in 2013. The denominator was defined as all patients ≥45 years of age with a joint pain Read code or a

diagnostic OA Read code. 80% of the clinical OA population were identified by joint pain Read code rather than diagnostic OA read codes. Of those patients identified through joint pain Read codes, 56.1% were women whilst of those identified through diagnostic OA Read codes, 61.6% were women. However, when compared to our study, the population was slightly younger, with a mean age of 52.7 years. The numerator was defined as those patients with an X-ray Read code for the hip, knee, hand, or wrist within 30 days either side of an OA consultation. Analysing this OA population, Yu et al. found that 22% of first time OA consulters received an X-ray in 2013, Yu et al. (2017) concluded that X-rays are likely over-used to diagnose OA.

Despite utilising a different database, my results are similar. I estimated the number of North Staffordshire patients consulting for OA with an associated X-ray request in 2015. The same "all OA" denominator definition was used as Yu *et al.* (2017). A similar numerator definition was also used. I additionally included Read codes for the foot in the numerator. The current study found that 31.8% of OA consulters across the nine GP practices in 2015 received an X-ray for OA.

Given the fact that OA can be diagnosed clinically, and X-ray features do not predict non-surgical treatment response the current studies estimate provides further evidence that from 2000-2012 X-rays are likely over-requested for OA. It is important to consider that not all the X-ray requests will have resulted in an X-ray being taken. However, these estimates are likely to be an under-estimate of the true rate of X-ray requests by practitioners. Yu et al. (2017) reports that their estimate is likely an under-estimate due to a lack of linked secondary care data. As a result, they were unable to capture the minority of patients who first presented with OA in secondary care.

My estimate is also likely to be an under-estimate of the total number of OA-relevant X-rays requested as, if a patient had multiple X-rays for different joints within 30 days of an OA consultation, only one X-ray was counted.

The estimated rate of X-ray requests in 2015 is likely to be more accurate than the estimated rate of X-ray requests in 2000-2012. The 2000-2012 estimate relied purely on the accuracy of practice coding. The quality of practice coding was variable. Two practices' coding was thought to be too

poor to be included in the analysis. Consequently from 2000-2012, the mean annual rate of X-ray requests for OA across seven practices was 17.3%.

An analysis of X-ray request rates using a different north Staffordshire database provides similar estimates (Edwards, 2017). The MOSAICS OA population in 2012 had a slightly higher proportion of female consulter (60.5%) compared to the CIPCA population (58.3%). The MOSAICS OA population was slightly older, with 47% of patients aged 45-64 (compared to 55.2% in CiPCA), 27% of patients aged 64-75 (compared to 22.5% in CiPCA), and 26% of patients aged >75 years or older (compared to 22.5% in CiPCA). 66% of the OA population were identified through a joint pain Read code. Edwards (2017) found that 18.5% of clinical OA consulters received an X-ray within 14 days of an OA consultation. The similar age and sex characteristics provide reassurance that comparisons could be made between my study and the study by Edwards (2017) for the period prior to 2013.

However, in my study, from 2013-2015 there was a sharp increase in X-ray request rates which coincided with the introduction of the clinical information system (Bostock, 2014). This clinical information system led to more accurate coding of X-ray requests and results. This suggests that the estimates of X-ray request rates from 2000-2012 are likely under-estimates resulting from inaccuracies in OA coding. It is unknown the impact quality of coding has had on X-ray request rates in the study by Edwards (2017). Despite the potential of an under-estimate in the X-ray request rate, both studies suggest that prior to 2019, X-ray request rates were higher than might reasonably be expected if clinical practice is strictly adherent to guidelines. This finding is supported by other international studies (Brand *et al.*, 2014; Smink *et al.*, 2014a; Yu *et al.*, 2017).

Furthermore, the current study did not directly investigate the appropriateness of the X-ray requests, so I cannot state to what degree X-rays are overused for OA. However, audit data suggests approximately 50% of joint X-ray requests follow guideline recommendations (Morgan *et al.*, 1997; Jacob & Thampy, 2015). This could explain why I found a consistently high rate of X-

ray requests from 2000-2012. To my knowledge, this study is the only UK study to examine the rate of X-ray requests for OA over time.

4.6.2 Trend in X-ray request rates

From 2000-2012, on average 17.3% of patients who consulted for OA each year received an X-ray. Overall, the rate of X-ray requests remained approximately constant, with a slight change in trend in 2003. However, marked inter-practice variation existed from 2000-2012. The reason for this inter-practice variation is unclear but may be due to structural factors such as access to imaging services, local education factors or changing practitioners within GP practices.

4.6.3 Changes in trends and relationship to guideline publication

From 2000-2003 the rate of X-ray requests increased by 2.6% per quarter. This is despite the Royal College of Radiologists (1998) guideline not recommending routine radiography for knee OA. This could represent a continuation of a trend found from 1994-1997, where the rate of X-ray requests for the lumbar spine increased despite guideline recommendations published in 1996 (Hollingworth *et al.*, 2002). The reason for this increase in X-ray requests is unknown. The rise in X-ray requests could reflect a broader rise in the use of all investigations in primary care. From 2000-2004 the rate of all investigations ordered in primary care rose by 20% per year (O'Sullivan *et al.*, 2018). This is speculated to be due to improved access to radiological services allowing practitioners to order tests to reassure patients and end consultations (O'Sullivan *et al.*, 2018; Hollingworth *et al.*, 2002). It may also represent a rise in patient consumerism, whereby patients are more willing to insist on an investigation from their doctor (Kravitz *et al.*, 2003).

Alternatively, the increasing trend in X-ray requests from 2000-2003 may be an artefact of an increase in the quality of coding. From 1999-2001 medical record training was provided to seven of the nine GP practices through cycles of audit and feedback (Porcheret *et al.*, 2004). Part of the audit process involved cross-referencing an electronic morbidity code with a drug prescription code. To score highly in this domain, practices had to have up to date morbidity codes. They therefore had to transcribe paper primary care records or hospital letters to patients' EHRs. This

training improved morbidity coding from 62% to 84%. As the high quality of morbidity coding required electronic transcribing of data, this training seems likely to have improved the electronic transcribing of X-ray requests. As practices became more proficient in electronic transcribing, more patients' X-rays would be entered on the database. This could partially explain the increasing trend in X-ray request rates from 2000-2003. However, from 2003-2012 the rate of X-ray request decrease by 0.5% per quarter. Reasons for this reduction in X-ray requests rates are explored below.

Two peaks in X-ray request rates were found from 2000-2012, the first in 2003 and the second in 2009. After each peak there is a reduction in X-ray request rates. Two guideline publications coincide within a year of each peak. The Royal College of Radiologists (2003) guideline and the NICE (2008) guideline. The joinpoint analysis found only one joinpoint indicating a statistically significant change in trend in the X-ray request rates. This joinpoint represents the same quarter as the publication of the Royal College of Radiologists (2003) guideline. This suggests that the Royal College of Radiologists (2003) guideline was temporally associated with a statistically significant change in the trend in X-ray request rates and the NICE (2008) guideline is associated with statistically insignificant reduction in X-ray request rates. Using the proximity of a joinpoint to a guideline publication date has previously been used to evaluate the effectiveness of guidelines on changing clinical practice (Huang *et al.*, 2010; Bedson *et al.*, 2013).

However, the role of guidelines in changing X-ray request behaviour is uncertain. Guidelines with vague and non-specific recommendations are less likely to change behaviour (Michie & Johnston, 2004). Both the Royal College of Radiologists (2003) guideline and the NICE (2008) guideline do not explicitly discourage X-ray use but rather suggest X-rays are not always necessary in the diagnosis of OA. Furthermore, when the Royal College of Radiologists (1998) guideline is compared to the Royal College of Radiologists guideline (2003), the 1998 guideline explicitly discourages the use of X-rays in the initial diagnosis of knee and hip OA, but the 2003 guideline recommends X-rays in specific circumstances. The Royal College of Radiologists (2003) guideline

is more supportive of X-ray use then its previous edition. As a result, it is unlikely that the Royal College of Radiology (2003) guideline or the NICE (2008) guideline were particularly effective in changing practitioners' behaviour. Furthermore, the current study showed significant practice variation, which was not strongly associated with guideline publication dates. This suggests that local factors at the practice level may be more responsible for changes in X-ray request rates.

However, even If I assume that the change in X-ray request rates is due to the publication of guidelines, the clinical relevance of this finding must be questioned. Other methods of reducing X-ray requests such as reminder systems and mailing GP guidelines have reduced X-ray request rates by 20% (Eccles *et al.*, 2001; Oakeshott, Kerry & Williams, 1994). In the context of these interventions, even if I assume the reduction in X-ray requests is due to the publication of guidelines, the -0.5% reduction in X-ray requests for OA per quarter from 2003-2012 is relatively small.

4.6.4 Potential determinants of an X-ray request for osteoarthritis

Obesity

Research into the determinants of an X-ray request for OA is sparse. One determinant identified is obesity (Rosemann *et al.*, 2008). The reasons for this are unclear. It may be due to obesity being a known risk factor for OA, but it may also be due to obese patients having higher consultation rates due to a higher number of co-morbidities (Van Dijk, Otters & Schuit, 2006; Reyes *et al.*, 2016). Each consultation may act as an opportunity to discuss a patient's OA, and potentially offer them an X-ray.

Frequency of consultation

Similarly, Edwards (2017) found that patients who visit their GP more than once, had an increased likelihood of an X-ray request for OA (OR:4.99; 95% CI:3.95, 6.31). This analysis also found that the more times a patient consults their GP for recorded clinical OA, the more likely they were to receive an X-ray request for OA. There are several possible explanations for this. If a

patient present to their GP multiple times, the GP may request an X-ray in the face of mounting pressure and to aid a patient's understanding of their disease (Porcheret, 2016). Furthermore, some GPs indicate frustration around a lack of management options for patients with OA (Egerton *et al.*, 2017). Requesting an X-ray can seem like a pro-active option which may reassure patients, improve satisfaction and strategically bring the consultations to a close (Alami *et al.*, 2011; Kerry *et al.*, 2000a; O'Sullivan *et al.*, 2018). Alternatively, the increased likelihood of receiving an X-ray for OA may be a result of surveillance bias, whereby patients who consult their practitioners more frequently have more opportunities for an X-ray to be requested. Further still, it is possible that patients with more severe OA consult more frequently, which result in an X-ray request for OA. This hypothesis could be examined through a cohort study, whereby patients could be categorised based on their baseline OA severity using the Western Ontario and McMaster Universities Arthritis Index (Bellamy *et al.*, 1988). The relative risk of receiving an X-ray for each OA severity group could be examined. This could reveal the potential relationship between the severity of OA and the rate of X-ray requests for OA.

Age

Bedson, Jordan & Croft (2005) conducted a case control study which explored the role of age in the decision to X-ray a patient. They found that patients under the age of 60 had an increased likelihood of an X-ray request for OA when compared to those over the age of 60. However, due to small sample sizes, the study was under-powered, and this relationship was found to be insignificant (adjusted OR:1.46; 95% CI: 0.73, 2.93). The current study found that when compared to 45-54-year olds, those who were 55-64 were at a statistically significantly increased likelihood of an X-ray request for OA, and those who were 75 years or older had a statistically significantly decreased likelihood of an X-ray request for OA. The mean age of first diagnosis for rheumatoid arthritis is 60 (Cea Soriano *et al.*, 2011; Gabriel, Crowson & O'Fallon, 1999). Rheumatoid arthritis is an important differential diagnosis for OA, and early X-rays are indicated in patients suspected of having rheumatoid arthritis in the hands and feet (NICE, 2018). This high rate of X-rays in those 55-64 could possibly indicate that GPs are appropriately using X-rays to rule out these differential diagnoses.

The decreased rate of X-rays in those over the age of 75 could be due to a GPs perception of OA. Alami *et al.* (2011) found that GPs viewed OA as "natural" and an "inevitable part of ageing". If practitioners view OA as analogous with old age, they may be less inclined to request an X-ray to confirm their diagnosis of OA.

Relative Deprivation

When adjusted for the practice a patient was registered, patients in national IMD quintiles 2, IMD 3, and IMD 4&5 (least deprived) were at an increased likelihood of an X-ray request for OA when compared to those in IMD 1 (most deprived). In other words, the lower the level of deprivation, the higher the likelihood of an X-ray request for OA. This was only statistically significant for patients in IMD 4&5. The higher levels of education in the less deprived groups, combined with more assertive patients, could result in increased pressure being placed on GPs, resulting in an increased likelihood of an X-ray (Filc *et al.*, 2014; Demeter *et al.*, 2005). Additionally, higher rates

of deprivation is associated with more severe OA (Thumboo, Chew & Lewin-Koh, 2002). In the presence of more severe OA, GPs may be more confident in making a clinical diagnosis of OA without radiographic confirmation.

Sex

The current study found that females had a slight increased likelihood of an X-ray, but this was not statistically significant. Smink *et al.* (2014a) found the opposite relationship, whereby males had an increased likelihood of an inappropriate X-ray for OA. Both studies found the magnitude of association was weak, suggesting a weak or non-existent relationship between sex and the decision to request an X-ray for OA.

Practice

Inequalities exist in OA care (McLeod *et al.*, 1997; Hunter, 2010). Bierma-Zeinstra *et al.* (2000a) identified practitioner variation in the decision to X-ray a patient for hip pain. My study found variation in X-ray request rates at the practice level. Additionally, I found that independent of patient factors and socioeconomic status, the decision to X-ray a patient was statistically significantly associated with the practice a patient was registered. The cause of this practice variation is unknown. Specific physician characteristics such as a greater appreciation of the risks of radiation, are associated with a reduced likelihood of requesting an X-ray for the lumbar spine (Smink *et al.*, 2014a; Baker, Lecouturier & Bond, 2006) . Furthermore, Smink et al. (2014) found that female GPs were less likely to X-ray for OA and Jackson et al. (2017) found that GPs with a higher OA workload were more likely to offer an X-rays for OA. Consequently, the decision to X-ray a patient is likely influenced by both patient and practitioner factors.

However, variation in the quality of EHRs could partially explain the discordance between practices; exemplified by the majority of the heterogeneity in X-ray request rates occurring prior to 2012, however following the introduction of automatic electronic recording in 2013, there is a reduction in the inter-practice variation in X-ray request rates.

4.6.5 Referral rates following a radiograph

Barten et al. (2017) found that patients who receive an X-ray for OA are more likely to be referred to secondary care. This study similarly found a high specialist referral rate following an X-ray request for OA. On average, 18.9% of X-rays resulted in a secondary care referral each year from 2000-2012. The reasons for this are not clear. It may be because GPs use X-rays to determine the appropriateness of a secondary care referral (Morgan *et al.*, 1997). This may be because GPs rely heavily on structural features to determine a patients wellbeing and therefore the appropriateness of a secondary care referral (Rosemann *et al.*, 2006a). However, this is against guideline recommendations. The British Orthopaedic Association (BOA) state that radiographic appearances of a patients joint should not influence a clinical orthopaedic referral decision (BOA, 2017).

An alternative explanation for the high referral rate following an X-ray is that GPs may request X-rays not for their own assessment, but for the benefit of the specialist's assessment (Morgan *et al.*, 1997). In this way, the decision to X-ray a patient may be related to the GP's referral intentions. Bedson, Jordan & Croft (2003) provide evidence for this, as they found that patients who were X-rayed for OA had an increased likelihood of an orthopaedic referral and decreased likelihood of a physiotherapy referral. BOA (2017) state that all patients with OA of the knee should receive an X-ray in secondary care and therefore perhaps ordering this X-ray prior to a specialist assessment could effectively streamline the referral process. However, as specialist X-ray views are necessary for OA, practitioners must ensure the correct views are ordered to avoid the duplication of X-ray requests and further unnecessary radiation exposure (Bopf *et al.*, 2010).

In this study, few X-rays were associated with a rheumatological referral. This could be an obvious finding, as both GPs and rheumatologists do not see OA as a rheumatologist's responsibility (Puchner *et al.*, 2016). However, this could also indicate that few X-rays for OA result in identifying serious missed pathology that require a change in the normal OA management pathway (Skou, Thomsen & Simonsen, 2014; Morgan *et al.*, 1997). Similarly,

Morgan et al. (1997) found that 90% of radiographs ordered for the knee resulted in normal or degenerative findings consistent with OA.

4.6.6 Strengths and limitations

A strength of this study is the improved quality of coding in 2015 due to the automatic recording of X-ray requests. As a result, the 2015 estimate is likely the most accurate estimate on the rate of X-ray requests for OA.

Furthermore, the decision to use a joinpoint analysis over a segmented logistic regression is a strength of this study, as the segmented logistic regression would assess the change in behaviour relative to a reference time point such as the guideline publication date. However, GPs may become aware of guidelines during the draft stage, or due to dissemination efforts implemented sometime after the publication date. Changes in practitioner behaviour related to guideline publication therefore could have been masked depending on the date used in a segmented regression analysis.

A specific strength of my joinpoint analysis was the use of quarterly estimates on the rate of X-ray requests. This provided more data points, which improved my confidence in the estimates obtained. In addition, due to the large number of data points, the model was able to evaluate for up to a possibility of nine joinpoints. This maximises the ability of the Joinpoint software to identify a model which best fits the observed values.

This study also has some limitations. Firstly, this study identified patients ≥45 years of age, with a diagnostic OA Read code or a joint pain Read code. However, diagnostic OA Read Codes associated with less common joint sites including the elbow or shoulder were not included.

The inclusion of a joint pain Read code allowed the identification of patients with early OA (Jordan *et al.*, 2016). However, it will also include patients that had other conditions other than OA, including rheumatological conditions, soft tissue, or bony injuries. This could over-estimate the rate of X-rays for OA and could have inflated the rate of rheumatological referrals following

an X-ray. Similarly, the referral rate following an X-ray is likely an under-estimate as only one referral was counted per person per year.

Furthermore, in this study it was not possible to assess when an X-ray was used to diagnose OA, and when an X-ray was used in the management process. The indication for each X-ray was not assessed to determine if they followed the guideline recommendations. As a result, this study was unable to assess the degree to which the X-rays were requested inappropriately.

The NICE (2014) OA guideline made similar diagnostic recommendation to the previous NICE (2008) OA guideline, so any additional impact on X-ray request rates from the updated NICE guideline is likely to be modest. These modest changes are likely to be concealed by the spike in X-ray request rates attributed to the introduction of the clinical information system from 2013-2015. As a result, the lack of continuous, consistent, and accurate recording of X-rays meant I was unable to assess the impact of the NICE (2014) guidelines on the diagnosis of OA.

Patients registered with a practice are likely to share more similarities with each other than patients between practices, as are clinicians working within practices. Therefore, adjusting for practice may additionally adjust at least partially for some other unknown patient confounding factors. Furthermore, by adjusting for practice ID, this considers potential practice level structural factors and practitioner characteristics which might impact the decision to request an X-ray for OA. The current study adjusted for practice level factors through a three-step logistic regression model. A multi-level model could in principle be used to estimate the level of variance in X-ray request explained at the levels of the patient, clinician and practice, though this complex methodology was not considered feasible for use in the (relatively small) CiPCA dataset.

4.6.7 Summary of finding and implications for future research.

In 2015, 31.8% of patients consulting for OA received an X-ray request. This is markedly higher than the 22% of incident OA consulters who received an X-ray request in 2013 (Yu et al., 2017). It is unknown to what degree the quality of coding is implicated in this disparity. However, if either

estimate are to be believed, this provides increasing evidence that X-rays are likely over-requested for OA.

However, it is possible that these figures over-estimate the number of patients who receive an X-ray for OA. Although non-attendance data specific to X-ray use is scarce (Lyon & Reeves, 2006), the rate of non-attendance to UK outpatient appointments following a GP referral was 9% in the second quarter of 2015 (NHS England, 2015). Furthermore, an Australian study found that patients aged 45-54 and 55-64 were less likely to attend medical imaging appointments compared to patients aged 65 and over (Mander *et al.*, 2018). If these determinants apply to the UK, this could indicate that many of the X-ray requests are not taken. This would seem plausible as from 2000-2015, 66% of the numerator of X-ray Read codes were Read codes related to X-ray requests, rather than results.

The trend in X-ray requests increased from 2000-2003, and then decreased from 2003-2012. The reversal of the trend in X-ray request rates is temporally associated with the publication of the 2003 RCR guideline. However, the subsequent RCR (2007) guideline, which made similar recommendations to the 2003 RCR guideline, appeared to have little impact on X-ray request rates.

This study found significant inter-practice variation. A qualitative investigation analysing practitioners' awareness of guideline recommendations, experiences with implementation strategies, and barriers to guideline adherence could help to identify alternative methods to changing practitioners' decisions around health care utilisation.

Patient factors including age, frequency of consultation, socioeconomic status and depression impact the likelihood of an X-ray. Due to a lack of reliably recorded ethnicity coding, it was not possible to assess the impact of ethnicity on the likelihood of an X-ray request for OA. I was able to assess the association between the practice a patient was registered and the likelihood of an X-ray request for OA. However, ideally an analysis that incorporated additional patient factors (particularly ethnicity, morbidity, BMI, site of OA and physical function), practitioner factors (such

as age, gender, OA workload and length of time since graduation), additional practice-level information (such as staffing ratios, distance to X-ray departments), and even Clinical Commissioning Group information (such as local musculoskeletal pathways of care) could be used to identify other factors which influence the likelihood of an X-ray request and may reveal unconscious biases in OA management.

4.7 Summary

This chapter has found that the overall rate in X-ray request from 2000-2012 remained generally constant. The joinpoint analysis found a slight increase in the trend of X-ray requests between 2000-2003 and then a slight decrease in the trend in X-ray requests from 2003- 2012. The publication of the Royal College of Radiologists (2003) guidelines was associated with a small reduction in X-ray request rates. Despite guidelines, nearly a third of OA consultations in 2015 were associated with an X-ray request. Factors which showed a strong correlation with the decision to X-ray included the frequency with which a patient consults for OA, the year in which they consult, patients aged ≥75 years of age and the practice a patient was registered.

5 Discussion

5.1 Summary of main findings

The systematic review of current and recent national and international guidelines relevant to the role of imaging in the diagnosis of osteoarthritis (OA) included 18 relevant guidelines published between 1998 and 2019. No guidelines produced by an organisation representing general practitioners recommended routine radiography to confirm a clinical diagnosis of OA. However, only three guidelines explicitly discouraged the routine use of plain radiographs to confirm a clinical diagnosis of OA.

An analysis of the CiPCA database, using continuous primary care electronic health record (EHR) data from nine practices in North Staffordshire, estimated that in 2015, 31.8% of patients who consulted for OA received at least one X-ray referral. Those receiving an X-ray request tended to be aged 55-64, lower rates of deprivation and more frequent consulters for OA. The practice a patient was registered was also associated with the likelihood of receiving an X-ray request for OA. A time-trend analysis, restricted to the period 2000-2012, before the introduction of the electronic requesting system, was then undertaken to determine whether this rate had changed over time and whether any such change coincided with the publication of any relevant UK guidelines.

A change in the trend of X-ray requests was identified and coincided with the publication of the Royal College of Radiologists (RCR) 2003 guideline. No statistically significant change in trend coincided with the publication of the RCR (2007), RCR (2012) and NICE (2008) guidelines. From this study I concluded that guidelines appear to have a limited impact on the use of X-rays for OA within primary care.

5.2 Comparison with existing literature.

Despite the lack of heterogeneity in the rate of X-ray requests from 2000-2012, there is a slight change in the underlying trend of X-ray request in 2003 which coincides with the publication of

the 2003 RCR guideline. It could be tempting to attribute this change in underlying trend to the publication of the RCR guideline, however evidence suggests that this change in trend could reflect broader structural changes within primary care. O'Sullivan et al. (2018) analysed the trend in all investigations requested by UK GPs from 2000-2015. From 2000-2004 the rate of investigations requested by GPs increased by 21% per year, however from 2004-2008 the rate of investigations ordered increased at a slower rate of 7.2% per year. Of all investigations it was noted that Imaging showed a rapid increase which then diminished, which O'Sullivan *et al.* (2018) attributed to improved access to imaging services, increased patient pressure and an over-estimation of the benefits of investigations. If I apply this finding to the current study, this could indicate that the 2003 joinpoint reflects a broader change in the use of imaging in primary care.

However, if the change in X-ray request rates is a result of the RCR guideline, the decreasing trend from 2003-2012 of 0.5% per quarter is markedly less efficacious than alternative implementation strategies, such as the introduction of reminder systems to UK general practices, which resulted in a 20% reduction in X-ray requests for OA within one year (Eccles *et al.*, 2001). Therefore, even if I assume that the 2003 change in X-ray request rates is a result of guideline publication, the subtle impact on X-ray request rates may suggest that guidelines without widespread implementation strategies are clinically ineffective in changing behaviour. There are several explanations for the limited impact of guidelines on the use of imaging in OA which are explored below.

5.2.1 Improving the impact of guidelines on the use of X-rays in primary care

Guidelines serve to make practitioners more aware of evidence-based practices. However, the current study found that despite guideline recommendations, practitioners continued to X-ray patients. One factor which may have limited the impact of guidelines on changing behaviour is poor dissemination.

Cumulating evidence suggests that historically the Royal College of Radiology (RCR) guidelines were poorly disseminated. A study conducted from 1994-1996 mailed primary care practitioners

the RCR guidelines. This led to a reduction in X-ray requests for the lumbar spine by 20% (Kerry *et al.*, 2000b). This capacity to improve guideline adherence through disseminating guidelines would suggest that at baseline, practitioners may be unaware or unfamiliar with the RCR guidelines. Furthermore, more recently a survey regarding the awareness of the Royal College of Radiology (2003) guidelines found that approximately half of doctors ranging from consultants to senior house officers were aware of abdominal, skull or chest RCR guideline recommendations, providing more evidence for poor awareness and availability of RCR guidelines (Mankad & Bull, 2005; Kumar, Mankad & Bhartia, 2007). Although this data is historic, if the subsequent guideline were poorly disseminated, this could explain the limited impact of guidelines on X-ray request rates.

However, although no studies have assessed the awareness of the NICE OA guideline, a study of 401 GPs found that 99% of respondents were aware of the NICE hypertension guideline (Heneghan *et al.*, 2007). If similar rates of awareness for the NICE OA guidelines are assumed, the high rate of X-ray requests is unlikely to be due solely to a failure in guideline dissemination.

However, awareness of a guideline does not equate to awareness of a specific guideline recommendation. A qualitative study of 30 GPs found that 46% reported awareness of a guideline, but not the specific recommendations (Lugtenberg *et al.*, 2009). This lack of awareness may be partly attributed to how the guideline is written. Difficult to read or long guidelines are a barrier to adherence (Gransjøen *et al.*, 2018). Additionally, imprecise language can impede guideline adherence (Michie & Johnston, 2004). A study measuring adherence to guideline recommendations found that clear and concise recommendations were followed by 67% of practitioners, but vague and ambiguous recommendations were followed by 36% of practitioners (Grol *et al.*, 1998). The systematic review undertaken in this thesis found only three guidelines which explicitly discouraged the routine use of radiography, all of which were lengthy guidelines (RACGP, 2018; NICE, 2008; EULAR *et al.*, 2017). This lack of clear and concise language could reduce practitioners ability to remember recommendations, reducing their capability to change

their behaviour (Michie & Johnston, 2004). This could partially explain why guidelines appeared to have a limited impact on X-ray request rates for OA.

Implementation strategies can drive behaviour change. Smink *et al.* (2014) attempted to change X-ray request rates through the introduction of a patient and practitioner education programme. This strategy recommended radiological assessment only in patients who had received paracetamol and lifestyle advice with unsatisfactory results. This recommendation was then disseminated through written publications, seminars, and outreach programmes (Smink *et al.*, 2014b). Following two years of this intervention, only 44% of X-ray requests were consistent with the stepped care strategy. This indicates that education alone may not lead to high adoption rates of guideline recommendations. However, the use of education programmes alongside reminder systems have been more effective in reducing X-ray request rates.

Jordan *et al.* (2017) conducted a randomised controlled trial to estimate the impact of a model OA consultation on several quality of care indicators. One indicator was the rate of X-ray requests for OA of the knee, hip, hand, or foot. Practices were randomised to an intervention arm and a control arm. The mean age of the intervention population was 66.2 (59% female); whilst the mean age in the control arm was 66.5 (61% female). The intervention arm comprised two components. One component included educational sessions on performing a model OA consultation, which consisted of simulated patient training sessions and seminars on the NICE OA guidelines. The second component included an e-template, which was triggered in patients ≥45 years of age with a first episode of joint pain. This e-template contained a reminder message which re-iterated that a clinical diagnosis of OA can be made without radiographs. These interventions provide evidence for potentially changing behaviour, as although the study was under-powered for this indicator, they reduced the rate of X-ray requests from 24.8% to 14.7%, with an adjusted odds ratio of 0.45 (CI: 0.12,1.72). This indicates that educational programmes and reminder systems may be a more effective alternative policy to changing practitioner's

behaviour. However, reminder systems alone may be a more cost-effective and practical strategy to reduce X-ray request rates nationally.

Eccles *et al.* (2001) conducted a randomised controlled trial to examine the impact of reminder systems on reducing X-ray requests for the knee and lower back. All practices received the Royal College of Radiology guidelines. The intervention practices also received a reminder attached to all X-ray results re-iterating that X-rays are not necessary for the routine diagnosis of OA. After one year, the rate of X-ray requests fell by 20%.

Reminder systems attempt to change behaviour partially through the re-education of practitioners, and partly through altering habits. Egerton *et al*. (2018) found that habit contributed to many practitioners continued use of X-ray to diagnose OA. However, the ability of strategies such as guidelines and reminder systems to change habits is likely dependent on the practitioners understanding of the relative benefits of the behaviour change, with a better understanding of the benefits of a recommendation associated with greater adoption (Lugtenberg *et al.*, 2009). The systematic review found seven guidelines which reported discordance between radiographic features and clinical symptoms and four guidelines suggested X-ray features do not predict non-surgical treatment response. However, only the RACGP (2018) and NICE (2008) guideline explained that radiography can potentially result in harm. This lack of reporting on the relative benefits and harms of radiography may drive the over-use of X-rays (Baker, Lecouturier & Bond, 2006). However, even when practitioners are aware why X-rays are not indicated routinely for OA, they may feel unable to change their practice (Morgan *et al.*, 1997).

One of the factors which may prevent practitioners from adhering to guidelines is patient pressure. Morgan *et al. (*1997) found patient pressure was a significant factor in 30% of X-ray requests for the knee. Similarly, a qualitative study of patients perspectives found that all patients believed X-rays should be requested for OA (Spitaels *et al.*, 2017). The reasons for this insistence on imaging are unclear. A possible explanation is that patients are uneducated about

the limitations of radiography for OA, which may be due to insufficient time in the consultation for GPs to educate patients (Alami *et al.*, 2011; Carmona-Terés *et al.*, 2017; Gransjøen *et al.*, 2018). As a result, the structural perception of OA, which is perpetuated through family, friends, and the media may over-emphasise the importance of X-ray findings (Rosemann *et al.*, 2006b; Papandony *et al.*, 2017; Hoffmann *et al.*, 2013; Spitaels *et al.*, 2017). This over-emphasis on X-ray imaging, in the context of a more consumerist patient attitude, may drive patients to insist on X-ray imaging for OA resulting in mounting patient pressure (Rosemann *et al.*, 2006b; O'Sullivan *et al.*, 2018).

This patient pressure could also explain the increased likelihood of X-ray requests found in patients who consulted more frequently. Alternatively, It is possible that these frequent consulters have more severe OA and therefore if their pain is out of proportion to usual symptoms, X-rays may be an appropriate use of resources (Royal College of Radiologists, 2017a).

5.3 Strengths and limitations

This thesis has several strengths. The search process for the systematic review was rigorous. Twenty sources of OA diagnostic guidelines were searched. Furthermore, each abstract and full text underwent dual screening. Dual screening is associated with a substantial improvement in detecting relevant articles (Waffenschmidt *et al.*, 2019). Consequently, this systematic review captured a wide range of evidence-based guidelines from various stakeholders on the diagnosis of OA in primary care. Furthermore, the critical appraisal of the guidelines was thorough. Prior to the critical appraisal, both researchers undertook an online training course. Each guideline was appraised by both researchers, with a percentage agreement of 86%. This reduced the impact of a single researcher's bias on assessing guideline quality.

The time trend analysis also had strengths. The introduction of automatic recording of X-ray requests from 2013 onwards improved the accuracy of the 2015 estimate and exposed the bias introduced by the under-recording of practices. This provided evidence that estimates of X-ray request rates which rely on manual recording by practices are likely to be under-estimates.

A final strength of the time trend analysis was the use of both joint pain and diagnostic OA Read codes. Through utilising joint pain Read codes, I am likely to have captured patients with earlier OA (Jordan *et al.*, 2016). This allowed for an assessment of X-ray use in the initial OA consultations, as well as in more established patients.

Limitations of this thesis include only one researcher undertaking the data extraction of the systematic review. Single data extraction has been shown to result in more errors and missed data (Buscemi *et al.*, 2006). It is possible that the systematic review may have missed or misinterpreted some diagnostic recommendations. Another limitation of the systematic review is the exclusion of non-English guidelines. This is because I believed guidelines published in English are more likely to have greater influence on UK practitioners, than non-English guidelines.

The time trend analysis had some limitations. EHR are prone to information biases introduced through inappropriate coding. This study was susceptible to bias introduced through poor coding by specific practices. I attempted to minimise this bias by excluding two practices with implausibly low X-ray request rates. However, despite my best efforts some coding bias is likely to have remained. This is because from 2000-2012 marked inter-practice variation existed in X-ray request rates, but after the introduction of the clinical information system from 2013-2015 there was a reduction in inter-practice variation. This could potentially indicate under-recording and over-recording in practices. If patients within an under-recording practice had specific characteristics, this has the potential to distort the associations found between patient's characteristics and the likelihood of receiving an X-ray request for OA.

An additional limitation in the time trend analysis is the inability to assess the appropriateness of the X-ray request. Based on the existing literature I have assumed a high degree of inappropriate X-rays are requested. However, in the unlikely event that all X-rays identified are appropriate, the lack of observed responsiveness to the publication of guidelines would indicate that guidelines are successful in guiding practitioner behaviour.

A further limitation of this thesis relates to data handling. This thesis originally aimed to assess the use of radiography in the diagnosis and management of OA from 2000-2019. Unfortunately, due to the periodical nature of downloading data from practice records, analysis was restricted to 2015. This prevented an evaluation of the potential impact of the 2014 NICE guidelines and prevented a contemporary assessment of X-ray request rates for OA.

5.4 Implications for clinicians

Guidelines produced by different organisations often make contradictory recommendations (Oxman, Glasziou & Williams, 2009). This may be due to an absence of evidence or variation in guideline quality (Oxman, Glasziou & Williams, 2009). These contradictions can reduce guideline adherence (Cabana *et al.*, 1999). This reduces the ability of guidelines to successfully meet the Quadruple Aims of healthcare policies (Sikka, Morath & Leape, 2015). It is important that practitioners can identify guidelines of high quality. The systematic review's critical appraisal of OA diagnostic guidelines could act as a resource to direct practitioners to higher quality OA guidelines.

Moreover, the systematic review also analysed how the presentation of OA varies between joint sites. Surprisingly, marked overlap in the presentation of OA across all joint sites was found. This provides evidence that in the routine clinical management of OA, OA can be broadly assessed as a single disease irrespective of joint site, as is suggested by NICE (Peat, Croft & Hay, 2001; NICE, 2014a).

With regards to imaging, the systematic review found that guidelines do not recommend routine radiography. This finding could dissuade practitioners from using imaging in patients with typical OA presentations. However, the emergence of the novel coronavirus 2019 has led practitioners to shift from face to face consultations to remote consultations (Greenhalgh, Koh & Car, 2020). A limitation of this shift to remote consultations is a reduction in the opportunity to perform an examination in the primary consultation. Six of the nine diagnostic criteria identified in the systematic review included a clinical feature which could only be elicited through examination.

Alternatively, three diagnostic criteria relied on radiographic or laboratory features. This leaves GPs with three options. They can either decide to bring the patient in to examine the joint, diagnose OA based on symptoms alone or request an X-ray for OA. If the GP is unsure of the clinical diagnosis, the decision to request an X-ray may be the most beneficial as it means that two appointments are not taken up by one complaint. This reduces the cost to the health service, and the reduced practice footfall reduces the risk of transmission of coronavirus to the patient and the doctor, benefiting the whole population. This use of X-rays meets the Quadruple Aims of healthcare which are to provide care which benefits patients, practitioners, and the health population at a reduced cost. However, if the increase in demand for imaging across the healthcare system results in longer waiting times, the delay in diagnosis may result in a delay in the initiation of core management strategies. This may result in worse outcomes for patients. As a result, the impact of the coronavirus pandemic may mean deciding what is an appropriate X-ray request becomes more difficult.

However prior to 2019, despite guideline recommendations, the literature suggests that approximately half of X-ray requests are inappropriate (Morgan *et al.*, 1997; Jacob & Thampy, 2015; Smink *et al.*, 2014a). My study provides study provides evidence that X-rays were likely over-used in the care of patients with OA. Considering this finding, practitioners should exercise caution when deciding to X-ray a patient for OA following a face-to-face consultation.

Particularly, caution should be exercised when assessing patients who consult more frequently for OA. The current study found that the more a patient consulted for OA, the higher the likelihood they would receive an X-ray. In these patients, practitioners must remain extra-cautious that the X-ray request is warranted, given the context that X-rays are not recommended in routine OA diagnosis, do not predict non-surgical treatment response and should not be used in determining the appropriateness of a secondary care referral (EULAR *et al.*, 2017; Wang, Oo & Linklater, 2018).

The decision to X-ray has also been linked to an increased likelihood of a secondary care referral (Barten *et al.*, 2017; Bedson, Jordan & Croft, 2003). Similarly, the current study found high physiotherapy and orthopaedic referrals following an X-ray for OA. The reason for the association between X-ray requests and physiotherapy referrals is unclear. A misconception is that specialists need X-rays to make their assessment (Morgan *et al.*, 1997). Improving awareness that X-rays are not necessary in a physiotherapy referral pathway could reduce the rate of inappropriate X-rays in general practice.

The appropriateness of the high rate of orthopaedic referrals following an X-ray is more complex. The British Orthopaedic Association (BOA) suggests that practitioner in primary care do not need to offer X-rays to refer patients to orthopaedics (BOA & BHS, 2017; BOA, 2017). However, BOA recommend that patients assessed for joint replacement should receive a specialist X-ray within secondary care (BOA, 2017). Practitioners may attempt to streamline this referral pathway by pre-emptively offering an X-ray prior to an orthopaedic referral (Baker, Lecouturier & Bond, 2006; Morgan *et al.*, 1997). However, if the views requested are different to the specialist view, this will result in repeated X-rays (Bopf *et al.*, 2010). Therefore, practitioners should ensure that any pre-emptive X-rays requested are consistent with orthopaedic guideline recommendations.

5.5 Implications for research

Except for the frequency by which a patient consults, the examined patient-level factors were only weakly associated with an X-ray request. More significantly associated with the decision to X-ray, was the practice a patient was registered. A qualitative examination into what practice and practitioner level factors drive X-ray requests could identify targets for guideline implementation strategies.

However, the reduction in practice variation from 2013 onwards, after the introduction of the clinical information system, indicates that the practice variation may be a result of variation in coding practices. An analysis of a primary care database with consistent and hight quality coding from 2000-2020, such as CPRD, could assess the extent to which the practice variation was a

result of heterogeneity in coding quality, and assess the impact of the 2014 NICE guidelines on X-ray request rates.

The shift from face to face consultations to remote consultations have several implications for research in this area. Currently there is little evidence to suggest that radiography improves diagnostic certainty in the context of typical clinical features (Skou, Thomsen & Simonsen, 2014). Remote consultations have reduced the ability for practitioners to elicit examination features. Research into the additional benefit of radiography when making a clinical diagnosis based purely on patients' symptoms is needed.

Furthermore, I speculate that the inability to examine patients due to remote consultations has resulted in higher rates of X-ray requests for OA. A segmented regression analysis to assess the impact of the coronavirus on X-ray request rates could confirm my suspicion GPs perceive a larger role for imaging because of remote consultations.

An additional limitation of the current study was the inability to assess the appropriateness of an X-ray using routinely recorded EHR data. This has been a similar limitation in other studies assessing the use of X-rays in OA (Brand *et al.*, 2014; Yu *et al.*, 2017). Research is needed to estimate the optimal proportion of patients that receive an X-ray request for OA each year, if all X-ray requests were appropriate. This target figure could help to place any future research evaluating X-ray request rates into a clinical context. Furthermore, this figure could be used as a target in audit cycles by practices to help drive down the rate of X-ray requests for OA.

The study was also unable to ascertain why guidelines had a limited impact on X-ray request rates. I hypothesised that this may be due to a lack of awareness of guidelines due to poor dissemination or vague wording, poor agreement with guidelines due to unclear scientific rationale and poor adoption due to a lack of widespread implementation strategies. A qualitative examination into practitioners' awareness of the role of X-rays in OA could reveal knowledge gaps which could be addressed by future guideline developers.

Guidelines need to be accompanied by implementation strategies (Fischer *et al.*, 2016). Reminder systems have been shown to decrease the rate of X-ray requests, which could potentially lead to savings for the health service (Jordan *et al.*, 2017; Eccles *et al.*, 2001; Grant *et al.*, 2012). The more practices which adopt these reminder systems, the higher the potential for savings in radiology. However, an economic evaluation into the cost-effectiveness and applicability of widespread reminder systems in UK general practice is needed before recommendations can be made to GP practices.

Similarly, education strategies have been shown to have a limited effect on the rate of X-ray requests for OA (Smink *et al.*, 2014a; Eccles *et al.*, 2001). Consequently, an analysis into other implementation strategies which improve the adoption of guideline recommendation could help to reduce the rate of X-ray requests for OA.

6 Conclusion

Guidelines consistently agree that patients with typical OA features should be diagnosed clinically. Guidelines also agree that the role of radiography for OA prior to 2019 was limited. However, this recommendation was usually presented with ambiguous wording and a lack of scientific rationale. It is perhaps unsurprising therefore that guidelines had a limited impact on X-ray request rates for OA from 2000-2012. If UK clinicians and commissioners believe that radiography continues to have a limited role in the diagnosis and management of OA despite remote consultations, new ways of increasing adherence to the guidelines need to be implemented. Potential patient benefits from this may include appropriate access to core OA treatments as well as access to specialist services depending upon clinical appropriateness rather than radiological severity. There may be some benefit from a reduction in population exposure to ionising radiation (although plain films of peripheral joints do not account for a high radiation burden on an individual level). The healthcare system may be made more efficient by more rational use of radiological investigations for common musculoskeletal conditions.

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Appendix

Appendix 1

Systematic review

This record cannot be edited because it is being assessed by the editorial team

1. * Review title.

Give the working title of the review, for example the one used for obtaining funding. Ideally the title should state succinctly the interventions or exposures being reviewed and the associated health or social problems. Where appropriate, the title should use the PI(E)COS structure to contain information on the Participants, Intervention (or Exposure) and Comparison groups, the Outcomes to be measured and Study designs to be included.

Systematic review of national and international guidelines and recommendations regarding the diagnosis of osteoarthritis (OA) in adults

2. Original language title.

For reviews in languages other than English, this field should be used to enter the title in the language of the review. This will be displayed together with the English language title.

3. * Anticipated or actual start date.

Give the date when the systematic review commenced, or is expected to commence.

28/10/2019

4. * Anticipated completion date.

Give the date by which the review is expected to be completed.

05/01/2020

5. * Stage of review at time of this submission.

Indicate the stage of progress of the review by ticking the relevant Started and Completed boxes. Additional information may be added in the free text box provided.

Please note: Reviews that have progressed beyond the point of completing data extraction at the time of initial registration are not eligible for inclusion in PROSPERO. Should evidence of incorrect status and/or completion date being supplied at the time of submission come to light, the content of the PROSPERO record will be removed leaving only the title and named contact details and a statement that inaccuracies in the stage of the review date had been identified.

This field should be updated when any amendments are made to a published record and on completion and publication of the review. If this field was pre-populated from the initial screening questions then you are not able to edit it until the record is published.

The review has not yet started: No

Review stage	Started	Completed
Preliminary searches	Yes	Yes
Piloting of the study selection process	Yes	Yes
Formal screening of search results against eligibility criteria	Yes	No
Data extraction	No	No
Risk of bias (quality) assessment	No	No
Data analysis	No	No

Provide any other relevant information about the stage of the review here (e.g. Funded proposal, protocol not yet finalised).

6. * Named contact.

The named contact acts as the guarantor for the accuracy of the information presented in the register record.

Connor Henry-Blake

Email salutation (e.g. "Dr Smith" or "Joanne") for correspondence:
Mr Henry-Blake

7. * Named contact email.

Give the electronic mail address of the named contact.

c.j.henry-blake@keele.ac.uk

8. Named contact address

PLEASE NOTE this information will be published in the PROSPERO record so please do not enter private information

Give the full postal address for the named contact.

9. Named contact phone number.

Give the telephone number for the named contact, including international dialling code.

10. * Organisational affiliation of the review.

Full title of the organisational affiliations for this review and website address if available. This field may be completed as 'None' if the review is not affiliated to any organisation.

Keele University

Organisation web address:
https://www.keele.ac.uk/

11. * Review team members and their organisational affiliations.

Give the personal details and the organisational affiliations of each member of the review team. Affiliation refers to groups or organisations to which review team members belong. **NOTE: email and country are now mandatory fields for each person.**

Mr Connor Henry-Blake. Keele University
Mr Simran Parmar. Keele University
Mr Jordan Higgs. Keele University
Dr Michelle Marshall. Keele University
Dr John Edwards. Keele University
Professor George Peat. Keele University
Mr Kane Treadwell. Keele university

12. * Funding sources/sponsors.

Give details of the individuals, organizations, groups or other legal entities who take responsibility for initiating, managing, sponsoring and/or financing the review. Include any unique identification numbers assigned to the review by the individuals or bodies listed.

Not applicable

Grant number(s)

13. * Conflicts of interest.

List any conditions that could lead to actual or perceived undue influence on judgements concerning the main topic investigated in the review.

None

14. Collaborators.

Give the name and affiliation of any individuals or organisations who are working on the review but who are not listed as review team members. **NOTE: email and country are now mandatory fields for each person.**

15. * Review question.

State the question(s) to be addressed by the review, clearly and precisely. Review questions may be specific or broad. It may be appropriate to break very broad questions down into a series of related more specific questions. Questions may be framed or refined using PI(E)COS where relevant.

To identify recommendations for the criteria used to diagnose OA in national and international guidelines, with particular interest in recommendations for radiological imaging.

To explore whether site of osteoarthritis influences the recommendations for diagnosis of OA.

16. * Searches.

State the sources that will be searched. Give the search dates, and any restrictions (e.g. language or publication period). Do NOT enter the full search strategy (it may be provided as a link or attachment.)

Search dates: 27/10/2019-30/10/2019

Bibliographic databases
• EMBASE
• MEDLINE
• CINAHL
• BNI
• AMED
• HMIC

Guideline specific websites
• Guideline central
• CPG infobase
• Guideline international network (GIN)

Website of professional bodies or organisations
• European League Against Rheumatism
• Osteoarthritis Research Society International
• National Institute for Health and Care Excellence
• Scottish intercollegiate Guideline Network
• American College of Rheumatology
• British Society for Rheumatology
• Royal college of General Practitioners
• Royal College of Radiologists
• American College of Radiologists

Other

Epistemonkos
Trip database

Restrictions
English language restriction

17. URL to search strategy.

Give a link to a published pdf/word document detailing either the search strategy or an example of a search strategy for a specific database if available (including the keywords that will be used in the search strategies), or upload your search strategy.

Do NOT provide links to your search results.

https://www.crd.york.ac.uk/PROSPEROFILES/155893_STRATEGY_20191024.pdf

Do not make this file publicly available until the review is complete

18. * Condition or domain being studied.

Give a short description of the disease, condition or healthcare domain being studied. This could include health and wellbeing outcomes.

Osteoarthritis (OA) is a disease of the movable joints resulting in activity related joint pain and stiffness. It is a prevalent disease, affecting 8.5 million people within the UK, and by the year 2020 will be the 4th leading cause of disability. Osteoarthritis is a significant health burden to the Health service within the UK, responsible for 2 million adults attending their GP in regards to their osteoarthritis per year. This burden on the economy isn't specific to the UK, as within the US between the years 2008-2011 there was a $122 billion earning loss per year as a direct result of osteoarthritis and allied conditions.

19. * Participants/population.

Give summary criteria for the participants or populations being studied by the review. The preferred format includes details of both inclusion and exclusion criteria.

Inclusion criteria
• Adults with osteoarthritis

Exclusion criteria
• Paediatric only guidelines
• Non-OA guidelines
• Purely osteoarthritis management

20. * Intervention(s), exposure(s).

Give full and clear descriptions or definitions of the nature of the interventions or the exposures to be reviewed.

National and international guidelines and recommendations concerning the diagnosis of osteoarthritis.

21. * Comparator(s)/control.

Where relevant, give details of the alternatives against which the main subject/topic of the review will be compared (e.g. another intervention or a non-exposed control group). The preferred format includes details of both inclusion and exclusion criteria.

Not applicable

22. * Types of study to be included.

Give details of the types of study (study designs) eligible for inclusion in the review. If there are no restrictions on the types of study design eligible for inclusion, or certain study types are excluded, this should be stated. The preferred format includes details of both inclusion and exclusion criteria.

• Guidelines / recommendations produced by national and international bodies
• Informed through systematic review of evidence
• Produced by guideline development groups or professional organisations
• Written in English
• Regarding diagnosis of OA

• Only the most recent guidelines developed through specific organisational bodies

23. Context.

Give summary details of the setting and other relevant characteristics which help define the inclusion or exclusion criteria.

24. * Main outcome(s).

Give the pre-specified main (most important) outcomes of the review, including details of how the outcome is defined and measured and when these measurement are made, if these are part of the review inclusion criteria.

To identify recommendations for the criteria used to diagnose OA in national and international guidelines, with particular interest in radiological imaging

To explore whether site of osteoarthritis influences the recommendations for diagnosis of OA.

* Measures of effect
Not applicable

25. * Additional outcome(s).

List the pre-specified additional outcomes of the review, with a similar level of detail to that required for main outcomes. Where there are no additional outcomes please state 'None' or 'Not applicable' as appropriate to the review

• Under what circumstances should alternative diagnosis be investigated
• What additional investigations may provide useful
• The role of imaging in diagnosing osteoarthritis and if this changes depending on joint site
• Number of articles retrieved
• Agree II score of guidelines

* Measures of effect
Not applicable

26. * Data extraction (selection and coding).

Describe how studies will be selected for inclusion. State what data will be extracted or obtained. State how this will be done and recorded.

The selection process will have 3 phases.
1. The title screen will be screened by CHB.
2. The abstract screen: 100% by CHB, 50% by JH and 50% by SP
3. Full text screen: 100% by CHB, 50% by JH and 50% by SP
a. Reason for exclusion here will need to be included

Those included for full text retrieval will be downloaded into a folder, with their full text reviewed. Inclusion for review will be recorded via the Excel spreadsheet. If not included for review, the reason for exclusion will be recorded based on the following
a. Setting based exclusion
i. Non English language (only after full text screen)
b. Study design based exclusion
ii. Guidelines/recommendations not based on systematic reviews of evidence
iii. Opinion pieces including editorials, letters, comments etc.
iv. Primary research e.g. Clinical trials
v. Guideline-related publications that summarise all or part of the original/full guidelines (only excluded when full text available)
vi. Gray literature-> unpublished literature
c. Population based exclusion
vii. Paediatric only guidelines
viii. Non-OA guidelines
ix. Spinal OA
d. Not most recent version

e. Full text not available
f. Other (please provide reason)

Disagreements will be resolved by discussion or by consulting a fourth reviewer if necessary.

Data extraction will be undertaken by two reviewers CHB and KT using an excel spreadsheet with the following subject headings. CHB will do the initial data extraction and quality appraisal, with KT checking it has been done correctly

- EXCEL table with the following columns
- Guideline ID
- publication year (or date)
- country
- organisation producing guideline
- specialties targeted
- new or adapted guideline
- number of development group members
- Site(s) of OA
- Setting
- site of OA
- specialties targeted
- guideline recommendations
- Guideline methods

27. * Risk of bias (quality) assessment.

Describe the method of assessing risk of bias or quality assessment. State which characteristics of the studies will be assessed and any formal risk of bias tools that will be used.

Quality assessment will be undertaken via the Agree II tool by CHB. This will be double reviewed by KT.
Before undertaking critical appraisal using the Agree II tool, the online booklet will be read by CHB and KT online training undertaken.

28. * Strategy for data synthesis.

Provide details of the planned synthesis including a rationale for the methods selected. This **must not be generic text** but should be **specific to your review** and describe how the proposed analysis will be applied to your data.

Narrative Synthesis will be undertaken by CHB individually. Prior to analysis the narrative synthesis Guidance on the Conduct of Narrative Synthesis in Systematic Reviews A Product from the ESRC Methods Programme will be read. Additional consulting with the systematic review team will be seeked prior to commencing the narrative synthesis.

The narrative synthesis will explore the areas of agreement and disagreement between the national guidelines with a particular focus on: the diagnostic criteria used to diagnose osteoarthritis, and if this changes dependent on joint site; under what circumstances should alternative diagnoses be investigated; what additional investigations may provide useful; the role of imaging in diagnosing osteoarthritis, and is this changes dependent on joint site.

29. * Analysis of subgroups or subsets.

State any planned investigation of 'subgroups'. Be clear and specific about which type of study or participant will be included in each group or covariate investigated. State the planned analytic approach.

Sub-group analysis will be undertaken based on population group. The subgroups analysis will separate the recommendations of osteoarthritis based on the joint site. The analysis will be undertaken by narrative synthesis.

30. * Type and method of review.

Select the type of review and the review method from the lists below. Select the health area(s) of interest for your review.

Type of review

Cost effectiveness	No
Diagnostic	Yes

Epidemiologic	No
Individual patient data (IPD) meta-analysis	No
Intervention	No
Meta-analysis	No
Methodology	No
Narrative synthesis	Yes
Network meta-analysis	No
Pre-clinical	No
Prevention	No
Prognostic	No
Prospective meta-analysis (PMA)	No
Review of reviews	No
Service delivery	No
Synthesis of qualitative studies	No
Systematic review	Yes
Other	No

Health area of the review

Alcohol/substance misuse/abuse	No
Blood and immune system	No
Cancer	No
Cardiovascular	No
Care of the elderly	No
Child health	No
Complementary therapies	No
COVID-19	No
Crime and justice	No
Dental	No
Digestive system	No
Ear, nose and throat	No

Education	No
Endocrine and metabolic disorders	No
Eye disorders	No
General interest	No
Genetics	No
Health inequalities/health equity	No
Infections and infestations	No
International development	No
Mental health and behavioural conditions	No
Musculoskeletal	Yes
Neurological	No
Nursing	No
Obstetrics and gynaecology	No
Oral health	No
Palliative care	No
Perioperative care	No
Physiotherapy	No
Pregnancy and childbirth	No
Public health (including social determinants of health)	No
Rehabilitation	No
Respiratory disorders	No
Service delivery	No
Skin disorders	No
Social care	No
Surgery	No
Tropical Medicine	No
Urological	No
Wounds, injuries and accidents	No
Violence and abuse	No

31. Language.

Select each language individually to add it to the list below, use the bin icon to remove any added in error.

English

There is not an English language summary

32. * Country.

Select the country in which the review is being carried out from the drop down list. For multi-national collaborations select all the countries involved.

England

33. Other registration details.

Give the name of any organisation where the systematic review title or protocol is registered (such as with The Campbell Collaboration, or The Joanna Briggs Institute) together with any unique identification number assigned. (N.B. Registration details for Cochrane protocols will be automatically entered). If extracted data will be stored and made available through a repository such as the Systematic Review Data Repository (SRDR), details and a link should be included here. If none, leave blank.

34. Reference and/or URL for published protocol.

Give the citation and link for the published protocol, if there is one

No I do not make this file publicly available until the review is complete

35. Dissemination plans.

Give brief details of plans for communicating essential messages from the review to the appropriate audiences.

Do you intend to publish the review on completion?

Yes

36. Keywords.

Give words or phrases that best describe the review. Separate keywords with a semicolon or new line. Keywords will help users find the review in the Register (the words do not appear in the public record but are included in searches). Be as specific and precise as possible. Avoid acronyms and abbreviations unless these are in wide use.

Guidelines; Diagnosis; Osteoarthritis; OA; Systematic review

37. Details of any existing review of the same topic by the same authors.

Give details of earlier versions of the systematic review if an update of an existing review is being registered, including full bibliographic reference if possible.

38. * Current review status.

Review status should be updated when the review is completed and when it is published. For newregistrations the review must be Ongoing.

Review_Completed_not_published

39. Any additional information.

Provide any other information the review team feel is relevant to the registration of the review.

40. Details of final report/publication(s) or preprints if available.

This field should be left empty until details of the completed review are available OR you have a link to a preprint.

Appendix 2

Table A-1: Medline (OVID) search strategy for the systematic review of national and international guidelines for the diagnosis of OA

1	exp Osteoarthritis/
4	osteoarth*.ti,ab,kf.
5	OA.ti,ab,kf.
6	arthrosis.ti,ab,kf.
7	(degenerative adj3 arthr*).ti,ab,kf.
8	or/1-6
9	practice guideline/
10	Practice Guidelines as Topic/
11	Consensus Development Conference/
12	"guideline development group".ab.
13	guideline*.ti,kw.
14	guidance.ti,kw.
15	(diagnos* adj criter*).ab.
16	recommendation*.ti,kw.
17	(practice adj (guideline* or guidance or recommendation*)).ab.
18	(clinical adj (guideline* or guidance or recommendation*)).ab.
19	(diagnos* adj5 (guideline* or guidance or recommendation*)).ab.
20	9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19
21	8 and 20

Appendix 3

AGREE II Item Criteria	No.
The overall objective(s) of the guideline is (are) specifically described.	1
The health question(s) covered by the guideline is (are) specifically described	2
The population (patients, public, etc.) to whom the guideline is meant to apply is specifically described.	3
The guideline development group includes individuals from all relevant professional groups.	4
The views and preferences of the target population (patients, public, etc.) have been sought.	5
The target users of the guideline are clearly defined.	6
Systematic methods were used to search for evidence.	7
The criteria for selecting the evidence are clearly described.	8
The strengths and limitations of the body of evidence are clearly	9
The methods for formulating the recommendations are clearly described.	10
The health benefits, side effects, and risks have been considered in formulating the recommendations.	11
There is an explicit link between the recommendations and the supporting evidence.	12
The guideline has been externally reviewed by experts prior to its publication.	13
A procedure for updating the guideline is provided.	14
The recommendations are specific and unambiguous.	15
The different options for management of the condition or health issue are clearly presented.	16
Key recommendations are easily identifiable.	17
The guideline describes facilitators and barriers to its application.	18
The guideline provides advice and/or tools on how the recommendations can be put into practice.	19
The potential resource implications of applying the recommendations have been considered.	20
The guideline presents monitoring and/or auditing criteria.	21
The views of the funding body have not influenced the content of the guideline.	22
Competing interests of guideline development group members have been recorded and addressed.	23

Appendix 4

AGREE II Item criteria no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
KT ACR-EJP	7	7	4	3	5	2	4	2	1	6	7	6	1	5	5	1	7	6	4	1	1	7	
CHB ACR-EJP	7	6	6	3	3	4	7	2	5	6	7	7	2	6	5	7	5	2	2	1	1	7	
KT ACR-A	7	6	4	3	5	3	7	4	6	6	1	7	1	3	6	1	7	6	4	1	1	7	
CHB ACR-A	7	6	6	3	3	4	7	2	5	6	7	7	2	6	5	7	5	2	2	1	1	7	
KT MaHTAS	7	7	7	7	1	7	7	4	3	6	7	7	5	1	3	5	6	3	4	2	1	5	
CHB MaHTAS	7	7	6	6	6	7	7	5	4	5	2	5	4	3	5	7	7	5	7	4	5	7	
KT DIG	7	5	7	7	2	7	7	6	6	7	7	7	3	5	6	7	7	6	4	2	6	5	
CHB DIG	7	6	7	6	7	7	7	6	7	7	7	7	7	7	6	7	7	7	6	5	5	7	
KT EULAR-K	6	5	5	6	1	7	6	6	5	7	1	6	1	1	7	7	7	3	3	4	1	3	
CHB EULAR-K	7	7	7	7	7	6	7	7	6	6	3	7	1	1	7	7	7	1	2	1	1	7	
KT EULAR-H	6	4	4	7	1	7	6	5	4	7	2	7	1	1	5	7	7	3	3	5	1	3	
CHB EULAR-H	7	5	5	7	1	3	7	7	4	7	3	7	1	1	6	7	7	1	3	1	1	4	
KT EULAR-PJ	7	7	5	7	7	7	7	6	5	7	2	7	1	4	5	5	5	4	5	2	1	4	
CHB EULAR-PJ	7	7	7	6	5	3	7	6	5	7	7	7	3	1	7	7	7	1	2	2	1	3	
KT EULAR/ EFFORT	6	5	4	5	1	3	3	3	2	3	2	1	2	4	7	6	7	2	1	1	1	3	
CHB EULAR/ EFFORT	7	7	7	3	1	7	3	1	2	3	5	4	3	5	6	7	7	2	2	3	1	1	
KT RACGP	7	7	7	6	7	7	7	7	7	7	7	7	1	6	7	7	7	6	6	5	3	7	
CHB RACGP	7	7	7	7	7	7	6	6	6	3	7	7	7	5	7	7	7	4	7	1	1	5	
KT APTA	7	6	7	7	7	7	7	7	5	4	3	7	5	7	7	7	7	5	3	3	2	7	
CHB APTA	7	6	6	6	6	7	7	7	7	3	7	7	7	7	7	7	7	7	7	4	1	7	
KT VA/DOD	7	7	7	6	7	7	6	6	7	7	7	3	1	6	7	7	5	5	6	2	2	1	
CHB VA/DOD	7	7	7	6	1	6	7	7	7	7	7	7	1	2	5	7	7	2	6	2	1	1	
KT NICE	7	7	7	7	7	7	7	6	6	7	5	7	3	1	6	7	6	4	5	7	3	1	
CHB NICE	7	7	7	7	7	6	7	7	7	4	7	7	1	5	7	7	7	4	7	7	7	7	
KT SIR	7	6	3	6	3	3	4	4	7	6	5	6	1	1	6	7	7	2	1	4	1	7	
CHB SIR	7	7	7	4	5	5	7	6	5	5	7	7	7	3	7	7	7	3	2	2	1	7	
KT RCR	7	7	6	6	2	4	4	3	6	3	4	3	3	3	6	1	7	5	5	2	1	1	
CHB RCR	7	2	7	6	1	7	2	1	4	1	7	2	3	4	5	1	7	4	5	1	2	1	
KT ACR-F	7	6	4	3	5	3	7	4	6	6	3	7	3	5	6	1	7	6	4	1	1	7	
CHB ACR-F	7	6	6	3	3	4	7	2	5	6	7	7	2	6	5	7	5	2	2	1	1	7	
KT ACR-K	7	6	4	3	5	3	7	4	6	6	3	7	3	5	6	1	7	6	4	1	1	7	
CHB ACR-K	7	6	6	3	3	4	7	2	5	6	7	7	2	6	5	7	5	2	2	1	1	7	
KT ACR-W	7	6	4	3	5	3	7	4	6	6	3	7	3	5	6	1	7	6	4	1	1	7	
CHB ACR-W	7	6	6	3	3	4	7	2	5	6	7	7	2	6	5	7	5	2	2	1	1	7	
KT ACR-H	7	6	4	3	5	3	7	4	6	6	3	7	3	5	6	1	7	6	4	1	1	7	
CHB ACR-H	7	6	6	3	3	4	7	2	5	6	7	7	2	6	5	7	5	2	2	1	1	7	

Appendix 5

Guideline	Scope and Purpose	Stakeholder Involvement	Rigour of Development	Clarity of Presentation	Applicability	Editorial Independence	Average score Across All Domains
ACR-EJP	86%	39%	60%	67%	17%	100%	61%
ACR-A	83%	42%	56%	69%	21%	100%	62%
MaHTAS	97%	94%	61%	75%	48%	88%	78%
DIG	92%	83%	91%	94%	69%	75%	84%
EULAR-K	86%	78%	57%	100%	17%	46%	64%
EULAR-H	69%	56%	56%	92%	21%	33%	55%
EULAR-PJ	94%	81%	69%	83%	21%	38%	64%
EULAR/EFORT	83%	39%	31%	94%	10%	33%	48%
RACGP	100%	97%	83%	100%	52%	88%	87%
APTA	92%	94%	84%	100%	50%	100%	87%
VA/DOD	100%	75%	75%	89%	38%	0%	63%
NICE	100%	97%	74%	94%	75%	71%	86%
SIR	86%	56%	68%	97%	17%	83%	68%
RCR	83%	56%	39%	58%	35%	0%	45%
ACR-F	83%	42%	70%	69%	21%	100%	64%
ACR-K	83%	42%	70%	69%	21%	100%	64%
ACR-W	83%	42%	70%	69%	21%	100%	64%
ACR-H	83%	42%	70%	69%	21%	100%	64%
Average Score Per Domain	88%	66%	69%	83%	32%	69%	

Appendix 6

Theme	Subtheme	OA Site	Recommendation	Reference
History and examination	Risk factors	Multiple joint	• Age>45	• RCR • NICE
			• Age >40	• SIR
			• Post-menopausal	• MaHTAS
			• Female • Family history • Occupational/ recreational usage	• MaHTAS • NICE
			• Obesity • Malalignment	• MaHTAS • NICE • SIR
			• Joint injury	• MaHTAS • NICE • SIR • RCR
			• OA at other sites	• MaHTAS • SIR
			• High bone density	• NICE
		Hand	• Age >.40 • Post-menopausal • Female • Family history • Obesity • Occupational/ recreational usage • Joint injury • Malalignment • High bone density	• EULAR-H
		Knee	• Age >50 • Female • Family history • Obesity • Occupational / Recreational usage • Joint injury • Malalignment • OA at other sites	• EULAR-K
		Hip	• Age >50 • Male • Obesity • Joint injury • Increased bone density	• APTA
		Wrist	Age >50	• DIG

		Shoulder	• Age >60	• DIG
	Symptoms and signs	Multiple joint	• Joint pain • Stiffness • Swelling • Crepitation • Reduced range of movement	• MaHTAS • RACGP • VA/DOD • NICE • SIR • APTA • EULAR-K • EULAR-H • DIG
		Hip	• Weakness of surrounding muscles • Reduced internal rotation	• APT
		Knee	• Varus/valgus deformity • Pain on patellofemoral compression • Joint line tenderness	• EULAR-K
		Hand	• Heberdeens nodes • Bouchards nodes • Lateral deviation of interphalangeal joint • Subluxation • Adduction of thumb base	• EULAR-H
Diagnosis	Important differential diagnosis	Multiple joint	• Inflammatory arthropathy • Crystal arthropathy • Infection • Trauma	• MaHTAS • RACGP • NICE • EULAR-H • RCR • VA/DOD • EULAR-K • EULAR/EFFORT • DIG
	Clinical/ radiographic	Multiple joint	• Clinical with radiograph as an adjunct.	• MaHTAS • EULAR PJ • VA/DOD • NICE • SIR • RACGP • DIG
		Knee	• Clinical with radiograph as an adjunct.	• RCR • EULAR-K
			• Clinical and radiographic	• ACR-K
		Hip	• Clinical with radiograph as an adjunct.	• APTA • ACR-H
			• Clinical and radiographic	• RCR
		Hand	• Clinical with radiographs as an adjunct	• EULAR-H

			• Clinical and radiographic	• ACR- H • ACR-EJP
		Wrist	• Clinical and radiographic	• ACR-W
		Ankle	• Clinical and radiographic	• ACR-A
		Foot	• Clinical and radiographic	• ACR-F
Imaging	First line imaging	Multiple joint	• X-ray	• MaHTAS • EULAR-PJ • RACGP • SIR • RCR • APTA • ACR-H • ACR-F • ACR-A • ACR-W • ACR-K • ACR-EJP • EULAR-H • EULAR-K • VA/DOD • EULAR/EFFORT • NICE
	Indications for radiography	Multiple joint	• Confirm the diagnosis when uncertain	• MaHTAS • EULAR-PJ • RACGP • SIR • RCR • EULAR-H • EULAR-K • VA/DOD • NICE
			• Rapid progression of symptoms/ change in clinical characteristics	• EULAR-PJ • RACGP
			• Assessing severity	• SIR • MaHTAS
	Secondary imaging modalities	Multiple joint	• MRI may be appropriate	• RCR • SIR • EULAR-PJ • ACR-H • ACR-W • ACR-K • ACR-F • ACR-A

				• ACR-EJP
			• Ultrasound may be appropriate	• RCR • SIR • EULAR-PJ • ACR-F • ACR-EJP • MaHTAS
			• CT may be appropriate	• RCR • SIR • EULAR-PJ • ACR-H • ACR-K • ACR-A • ACR-EJP
	X-ray features	Multiple joint	• Joint space narrowing • Osteophyte • Subchondral sclerosis • Subchondral cyst	• RACGP • SIR • NICE • APT • ACR-K • EULAR-K • DIG • EULAR-H
	Scientific rational	Any OA site	• Radiological features do not necessarily correlate with symptoms	• MaHTAS • RACGP • NICE • APTA • EULAR-K • EULAR-PJ • DIG
			• Radiography is not useful in the typical non-surgical management of OA. (does not predict treatment response, not useful in assessing typical progression)	• SIR • DIG • EULAR-PJ • RACGP
			• Explicitly discourages routine radiographs	• RACGP • NICE • EULAR-PJ
			• Unlinked to result in any serious missed pathology	• RACGP • NICE

Appendix 7

Joint	Guideline	X-ray views recommended
Hip	VA/DOD	• Weight bearing AP pelvis • Non weight bearing frog lateral of the affected hip
	MaHTAS	• Weight bearing AP

		• Weight bearing standing
	RACGP	• Weight bearing
Knee	EULAR-P	• Weight bearing • Patellofemoral
	RACGP	• Weight bearing
	VA/DOD	• Weight bearing AP • Weight bearing flexed view in 30 degrees of flexion • Lateral view • skyline view
	SIR	• Weight bearing and patellofemoral
	EULAR-K	• Weight bearing • Semi flexed PA (MTP) • Lateral view • Skyline view
	EULAR/EFFORT	• Weight bearing AP • X-rays in two planes
	MaHTAS	• Weight bearing AP • Weight bearing standing
	ACR-K	• AP or Rosenberg or tunnel • Standing patellar view • Standing Lateral view
Shoulder	DIG	• AP internal rotation • AP external rotation • Axillary view • Y Scapula view • Supraspinatus outlet view
Ankle	ACR-A	• Anteroposterior • Lateral • Mortise
Wrist	ACR-W	• Posterior-Anterior neutral position and rotation • Lateral views neutral position and rotation • One or more oblique view
Hand	SIR	• PA radiographs of both hands
	ACR-I	• PA

		• Oblique • Lateral • semi supinated
	EULAR-H	• PA both hands single film
Foot	ACR-F	• Anteroposterior • Lateral • mortise views

Appendix 8

Table A7: The future research questions recommended by OA diagnostic guidelines	
EULAR-K	Development of internationally agreed criteria sets for diagnosis of knee OA for clinical practice, clinical trials, and epidemiological studies.
	Development of a scoring system for accurate diagnosis of knee OA based on the sensitivity and specificity of risk factors and symptoms and signs.
	Delineation of the attributable risk factor profile, for both development and progression, for each suggested subset of knee OA
	Development of diagnostic criteria for early symptomatic knee OA (e.g., by prospective investigation of people with knee pain who fulfil criteria of knee OA several years later).
	Investigation of whether individual pain patterns (usage related, episodic, night pain) have different utility as diagnostic markers of knee OA.
	Determination of clinical, diagnostic, and prognostic relevance of MRI changes in knee OA.
	Determination of the utility of ultrasonography in the diagnosis and prognosis of knee OA
	Assessment of the possible role of biomarkers (including genetic markers) in the early diagnosis, phenotypic characterisation, and prediction of outcome of knee OA
	Assessment of the accuracy of red flags in identifying serious pathology in patients presenting with knee symptoms.
EULAR-H	The relative utility of imaging techniques (plain x rays, MRI, ultrasonography, scintigraphy) in early diagnosis and evaluation of progression of the HOA subsets needs to be determi
	Risk factors for development and long-term clinical outcome of the different subsets of HOA need to be determined.
	Potential biomarkers of bone, cartilage, synovium, and inflammation should be examined in HOA subsets for utility in terms of early diagnosis, assessment of disease activity and prediction of outcome.
	Diagnostic and classification criteria to better define HOA and its subsets need to be developed and validated.
	Further studies are required to confirm the associations between HOA and systemic risk factors such as menopausal state, bone density, obesity, and metabolic syndrome, and to explain the mechanisms that underlie such associations.

	The genetic factors that predispose to the different phenotypes of HOA need to be identified.
EULAR-PI	Methodologically robust studies to explore the added value of imaging (any modality) to clinical diagnosis or differential diagnosis
	What is the cost-effectiveness of imaging in OA clinical practice
	Is imaging able to help identification of subgroups/phenotypes that may have different trajectories and enable targeted treatment based on these subgroups
	There is a need to understand if using imaging to measure response to therapy is of clinical benefit. This may require evaluation of novel imaging technologies that are able to sensitively detect change in relevant joint structures
	Quality studies are required to explore imaging (any modality) features that predict response to specific therapies
	There is a need for more research concerning the benefits of imaging in less commonly studied osteoarthritis sites such as the foot and shoulder
	What is the added value of weight bearing vs non weight bearing X-rays for hip osteoarthritis?

Appendix 9

Table A8: The joint pain and OA diagnostic Read code for the OA population

Code	Term
1M10	Knee pain
1M11	Foot pain
1M13	Ankle pain
N05	Osteoarthritis and allied disorders
N050	Generalised osteoarthritis - OA
N050	Generalised osteoarthritis-OA
N0500	Generalised OA-site unspecif.
N0501	Bouchards nodes
N0501	Generalised OA-hand
N0501	Heberdens nodes
N0501	Heberdens' nodes
N0502	Generalised OA-multiple sites
N0502	Osteoarthritis -multiple joint
N0503	Bouchard's nodes with arthrop
N0503	Bouchards nodes with arthropathy
N0504	Primary general osteoarthrosis
N0504	Primary generalized osteoarthrosis
N0505	Secondary multiple arthrosis
N0506	Erosive osteoarthrosis
N0507	Heberden's nodes + arthropathy
N0507	Heberdens nodes with arthropathy
N050z	Generalised osteoarthritis NOS
N051	Local.primary osteoarthritis
N051	Localised primary osteoarthritis
N0510	Local.primary OA-site unspec.
N0511	Local.primary OA-shoulder regn
N0512	Local.primary OA-upper arm
N0512	Localised, primary osteoarthritis of the upper arm
N0513	Local.primary OA-forearm
N0514	Local.primary OA-hand
N0514	Localised, primary osteoarthritis of the hand
N0515	Local.primary OA-pelvic/thigh
N0516	Local.primary OA-lower leg
N0517	Local.primary OA-ankle/foot
N0517	Localised, primary osteoarthritis of the ankle and foot
N0518	Local.primary OA-other specif
N0519	Primary coxarthrosis bilateral
N0519	Primary coxarthrosis, bilat
N051A	Coxarthr from dysplasia, bilat
N051B	Primary gonarthrosis, bilat
N051C	Pr arth 1st carpometcp jts,bil
N051C	Pr arth 1st carpometcp jtsbil
N051D	Local prim osteoarth wrist
N051E	Local prim osteoarth toe
N051E	Localised, primary osteoarthritis of toe
N051F	Local prim osteoarth elbow

N051z	Localised primary OA NOS
N051z	Localised, primary osteoarthritis NOS
N052	Local.secondary osteoarthritis
N0520	Local.secondary OA-site unsp.
N0521	Local.secondary OA-shoulder
N0522	Local.secondary OA-upper arm
N0523	Local.secondary OA-forearm
N0524	Local.secondary OA-hand
N0525	Local.secondary OA-pelv./thigh
N0526	Local.secondary OA-lower leg
N0527	Local.secondary OA-ankle/foot
N0527	Localised, secondary osteoarthritis of the ankle and foot
N0528	Local.secondary OA-other spec.
N0529	Post-traum coxarthrosis, bilat
N052A	Post-traum gonarthrosis, bilat
N052B	Pst-tr art 1 carpometcp jt bil
N052C	Post-trauma gonarth, unilat
N052z	Localised secondary OA NOS
N053	Localised OA unspecified
N0530	Local.OA unsp.-site unspecif.
N0531	Local.OA unsp.-shoulder region
N0532	Local.OA unsp.-upper arm
N0533	Local.OA unsp.-forearm
N0534	Local.OA unsp.-hand
N0535	Hip osteoarthitis NOS
N0535	Local.OA unsp.-pelvic/thigh
N0535	Otto's pelvis
N0536	Local.OA unsp.-lower leg
N0536	Patellofemoral osteoarthritis
N0537	Local.OA unsp.-ankle/foot
N0537	Localised osteoarthritis, unspecified, of the ankle and foot
N0538	Local.OA unsp.-other specified
N0539	Arthros 1st CMC joint unspec
N0539	Arthros 1st CMC joint, unspec
N053z	Localised OA unspecified NOS
N054	Oligoarticular OA unspecified
N054	Oligoarticular OA, unspecified
N0540	Oligoartic OA, unsp-unsp sites
N0541	Oligoartic OA, unspec-shoulder
N0542	Oligoartic OA, unspec-upp arm
N0543	Oligoartic OA, unspec-forearm
N0544	Oligoartic OA, unspec-hand
N0545	Oligoartic OA, unspec-pelv/thi
N0546	Oligoartic OA, unspec-leg
N0547	Oligoartic OA unspec-ank/foot
N0547	Oligoartic OA, unspec-ank/foot
N0548	Oligoartic OA unspec-oth site
N0548	Oligoartic OA, unspec-oth site
N0549	Oligoartic OA, unspec-multiple
N054z	OA,1 site +,unspecified NOS
N05z	Joint degeneration
N05z	Osteoarthritis NOS
N05z0	Osteoarthritis NOS-site unspec

N05z0	Osteoarthritis NOS, of unspecified site
N05z1	Osteoarthritis -shoulder joint
N05z1	Osteoarthritis NOS-shoulder
N05z1	Osteoarthritis NOS, of shoulder region
N05z2	Elbow osteoarthritis NOS
N05z2	Osteoarthritis - elbow joint
N05z2	Osteoarthritis NOS-upper arm
N05z2	Osteoarthritis NOS, of the upper arm
N05z3	Osteoarthritis - wrist joint
N05z3	Osteoarthritis NOS of the forearm
N05z3	Wrist osteoarthritis NOS
N05z4	Finger osteoarthritis NOS
N05z4	Osteoarthritis - hand joint
N05z4	Osteoarthritis NOS of the hand
N05z4	Osteoarthritis NOS-hand
N05z4	Osteoarthritis NOS, of the hand
N05z4	Thumb osteoarthritis NOS
N05z5	Hip osteoarthritis NOS
N05z5	Osteoarthritis - hip joint
N05z5	Osteoarthritis NOS-pelv./thigh
N05z5	Osteoarthritis - hip joint
N05z6	Knee osteoarthritis NOS
N05z6	Osteoarthritis - knee joint
N05z6	Osteoarthritis NOS-lower leg
N05z7	Ankle osteoarthritis NOS
N05z7	Foot osteoarthritis NOS
N05z7	Osteoarthritis - ankle/foot
N05z7	Osteoarthritis NOS-ankle/foot
N05z7	Toe osteoarthritis NOS
N05z8	Osteoarthritis - other joint
N05z8	Osteoarthritis NOS-other spec
N05z9	Osteoarthritis NOS of shoulder
N05z9	Osteoarthritis NOS, shoulder
N05zA	OA NOS-sternoclavicular joint
N05zB	OA NOS-acromioclavicular join
N05zB	OA NOS-acromioclavicular joint
N05zC	OA NOS-elbow
N05zC	Osteoarthritis NOS of elbow
N05zD	OA NOS-dist radio-ulnar joint
N05zE	OA NOS-wrist
N05zE	Osteoarthritis NOS of wrist
N05zF	OA NOS-MCP joint
N05zF	Osteoarthritis NOS of MCP joint
N05zG	OA NOS-PIP joint of finger
N05zH	OA NOS-DIP joint of finger
N05zJ	OA NOS-hip
N05zJ	Osteoarthritis NOS of hip
N05zJ	Osteoarthritis NOS, of hip
N05zK	OA NOS-SI joint
N05zL	Osteoarthritis NOS of knee
N05zL	Osteoarthritis NOS, of knee
N05zM	OA NOS tibio-fibular joint
N05zN	OA NOS-ankle

N05zN	Osteoarthritis NOS of ankle
N05zP	OA NOS-subtalar joint
N05zQ	OA NOS-talonavicular joint
N05zR	OA NOS-other tarsal joint
N05zS	OA NOS-1st MTP joint
N05zT	OA NOS-lesser MTP joint
N05zU	OA NOS-IP joint of toe
N05zz	Osteoarthritis NOS
N06z3	Arthropathy NOS-forearm
N06z3	Wrist arthritis NOS
N06z4	Arthropathy NOS of the hand
N06z4	Arthropathy NOS-hand
N06z4	Hand arthritis NOS
N06z5	Hip arthritis NOS
N06z6	Knee arthritis NOS
N06z7	Ankle arthritis NOS
N06z7	Foot arthritis NOS
N094	Ache in joint
N094	Pain in joint - arthralgia
N0940	Arthralgia - site unspecified
N0940	Arthralgia of unspecified site
N0943	Arthralgia - forearm
N0943	Wrist joint pain
N0944	Arthralgia - hand
N0944	Arthralgia of the hand
N0944	Hand joint pain
N0945	Arthralgia - pelvic/thigh
N0945	Coxalgia
N0945	Hip joint pain
N0946	Arthralgia - lower leg
N0946	Arthralgia of the lower leg
N0946	Knee joint pain
N0947	Ankle joint pain
N0947	Ankle/foot joint pain
N0947	Arthralgia - ankle/foot
N0947	Arthralgia of the ankle and foot
N094F	Arthralgia of wrist
N094G	Arthralgia of MCP joint
N094H	Arthralgia of PIP joint of finger
N094K	Arthralgia of hip
N094K	Hip pain
N094M	Arthralgia of knee
N094P	Arthralgia of ankle
N094T	Arthralgia of 1st MTP joint
N094W	Anterior knee pain
N2450	Finger pain
N2450	Hand pain
N2450	Thumb pain
N2451	Foot pain
N2451	Toe pain

Appendix 10

Table A10: The X-ray Read codes for the OA population

Code	Term
5213	Plain X-ray result normal
5258	Plain X-ray sacrum/coccyx
52580	Plain X-ray sacrum normal
527Z	Plain X-ray pelvis NOS
52930	Plain X-ray carpus normal
52951	X-ray phalanges of fingers abnormal
52A3	Plain X-ray hip joint
52AA	Plain X-ray ankle joint
52AA0	Plain X-ray ankle joint normal
52AZ	Plain X-ray hip/leg NOS
52B50	Plain X-ray of toes normal
52B7	Calcaneum X-ray
52B70	Calcaneum X-ray normal
OXX114	Plain X-ray of wrist
OXX119	Plain X-ray pelvis
52581	Plain X-ray sacrum abnormal
52583	Plain X-ray coccyx abnormal
5272	Plain X-ray pelvis abnormal
5275	Plain X-ray ilium
5289	Plain X-ray of wrist
528C	Plain X-ray humerus
5291	Plain X-ray hand normal
5293	Plain X-ray carpus
52931	Plain X-ray carpus abnormal
52932	Plain X-ray scaphoid normal
52933	Plain X-ray scaphoid abnormal
5294	Plain X-ray metacarpals
5296	X-ray phalanges of thumb
52960	X-ray of thumb normal
52A6	Plain X-ray shaft of femur
52A71	Plain X-ray knee abnormal
52A80	Plain X-ray patella normal
52A81	Plain X-ray patella abnormal
52B51	Plain X-ray of toes abnormal
OXX120AB	Plain X-ray hip joint abnormal
OXX125A	Plain X-ray ankle joint abnormal
52	Plain radiography
5211	Plain X-ray requested
52582	Plain X-ray coccyx normal
527	Plain X-ray pelvis
5271	Plain X-ray pelvis normal
5278	Plain X-ray sacro-iliac joint
52890	Plain X-ray of wrist normal
52891	Plain X-ray of wrist abnormal
528C1	Plain X-ray humerus abnormal
52961	X-ray of thumb abnormal
529Z	Plain X-ray hand NOS
52A	Plain X-ray hip/leg
52A31	Plain X-ray hip joint abnormal

52A7	Plain X-ray knee
52A8	Plain X-ray patella
52AB	Stress X-ray knee
52AD	Plain X-ray femur
52AD1	Plain X-ray femur abnormal
52B8	Forefoot X-ray
52BZ	Plain X-ray foot NOS
52Z	Plain bone X-ray NOS
EMISREQ|52A3	Plain X-ray requested
OXX120N	Plain X-ray hip joint normal
5214	Plain X-ray result abnormal
528C0	Plain X-ray humerus normal
529	Plain X-ray hand
5292	Plain X-ray hand abnormal
5295	X-ray phalanges of fingers
52950	X-ray phalanges of fingers normal
52A1	Plain X-ray hip/leg normal
52A2	Plain X-ray hip/leg abnormal
52A30	Plain X-ray hip joint normal
52A70	Plain X-ray knee normal
52AA1	Plain X-ray ankle joint abnormal
52AD0	Plain X-ray femur normal
52B	Plain X-ray foot
52B1	Plain X-ray foot normal
52B2	Plain X-ray foot abnormal
52B4	Plain X-ray metatarsal bones
52B5	Plain X-ray phalanges of toes
52B6	X-ray phalanges of hallux
52B71	Calcaneum X-ray abnormal

Appendix 11

Table A11: The potentially relevant specialist referral Read codes

8BAH	Exercise on prescription
8CAc	Advised to contact physiotherapy triage service
8H77.	Refer to physiotherapst
8H7q.	referral for exercise therapy
8H7s.	Refferal to physical activity programme
8HHc.	Referred for exercise programme
9NJ3.	In-house Physio
9NJ4.	In-house physiotherapy doicillary visit
9NJk.	In-house physiotherapy first appointment
9NJm.	In-house physiotherapy follow up appointment
9N0F.	Seen in physiotherapy dept
8H76.	Refer to dietician
8HHH.	Refer to weight management programme
8H7J.	Refer to occupational therap.
8H7Q.	Refer to surgical fitter
8H7R.	Refer to chiropodist
8H7S.	Refer to orthotist
8H7k.	Referral to community-based podiatry service
8H7l.	Referral to hospital-based podiatry service
8H7m.	Referral to private state registered podiatry service
8H4B.	Referred to rheumatologist
8H54.	Orthopaedic referral
8H69.	Refer to pain clinic